DOCUMENT RESUME

ED 339 861 CE 059 796

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TITLE Computer Aided Manufacturing.
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SPONS AGENCY Office of Vocational and Adult Education (ED), Washington, DC.
PUB DATE 91
CONTRACT V100A00063-90
NOTE 111p.; For related documents, see CE 059 793-795.
PUB TYPE Guides - Classroom Use - Teaching Guides (For Teacher) (052)

EDRS PRICE MF01/PC05 Plus Postage.
DESCRIPTORS College Programs; Community Colleges; Computer Assisted Design; *Computer Assisted Manufacturing; Computer Science; *Computer Software; Course Descriptions; Industrial Education; *Industrial Training; Job Training; Numerical Control; Resource Centers; Retraining; Technical Education; *Technological Advancement; Two Year Colleges
IDENTIFIERS Northampton County Area Community College PA; Programable Logic Control

ABSTRACT

This document contains course outlines in computer-aided manufacturing developed for a business-industry technology resource center for firms in eastern Pennsylvania by Northampton Community College. The four units of the course cover the following: (1) introduction to computer-assisted design (CAD)/computer-assisted manufacturing (CAM); (2) CAM requirement analysis; (3) CAM software and evaluation; and (4) SMARTCAM. Exercises and transparency masters are included. Appendixes consist of part drawings, "hot key" definitions, and an outline of a programmable logic controls workshop. (KC)

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ED339861

COMPUTER AIDED MANUFACTURING

Developed by
Gerard Insolia

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Special acknowledgement to the following organizations for documentation used in this training program:

Point Control Co.

Northeast Manufacturing Technology Center (NEMTC)
Rennsalear Polytechnical Institute
Rennsalear, New York

OUTLINE: COMPUTER AIDED MANUFACTURING

I. INTRODUCTION
   1. Rationale for CAD/CAM
   2. CAD/CAM Hardware
   3. CAD/CAM Software
   4. CAD-to-CAM Interface
   5. CAM-to-CNC Interface

   Objective: Give the student a perspective of CAM that includes why CAM is used, how it is implemented, and how it affects other areas of the company.

II. CAM REQUIREMENTS ANALYSIS
   1. Part Analysis
   2. CNC Machine Tools
   3. CAM Requirement
   4. CAD System
   5. Workforce

III. CAM SOFTWARE EVALUATION
   1. General Operation
   2. System Types
   3. Editing
   4. CAD Interfaces
   5. Post Processors
   6. User Skupoport
   7. Cost Estimates
   8. Evaluation

IV. SMARTCAM
   1. Capabilities
   2. Available Functions
   3. General Method of Use
   4. User Interface
   5. Preparing to Write a Program
   6. Process Modeling
   7. Generating CNC Code
   8. Editing Code
   9. Communications

I. INTRODUCTION

1. Rationale for CAD/CAM
2. CAD/CAM Hardware
3. CAD/CAM Software
4. CAD to CAM Interface
5. CAM to CNC Interface

Definitions:

CAD	Computer Aided Design
CAM	Computer Assisted Machining
CNC	Computer Numerical Control

I. INTRODUCTION

1. Rationale for CAD/CAM

Increased productivity

Better quality products

Better communications

Integrated design & manufacturing
- **Modeling - product & process**
- **Analysis - multiple conditions**
- **Review - check accuracy**
- **Documentation!!**

Reduced prototype costs

Faster response to customers

I. INTRODUCTION

2. CAD/CAM Hardware

a. Operator Input Devices

Mouse
Keyboard
Digitizing Tablet
Trackball, Joystick

b. Computer

Central Processing Unit (CPU)
Memory (RAM)
Primary Storage (Hard Disk)
Secondary Storage (Floppy Disk)
Floating Point Processor (optional)

c. Output Devices

Monitor
Printer
Plotter
Disk Drives, Tape Drives

I. INTRODUCTION

3. CAD/CAM Software

a. Operating System

DOS
UNIX, XENIX, AIX
OS/2
Network Operation System

b. Application Program

CAM System
CAD System
Postprocessor

c. Utilities

Translators (CAD to CAM)
Communications (CAM to CNC)

I. INTRODUCTION

4. CAD to CAM Interface

IGES
DXF
CADL
VDA-FS
PDES

Translators allow geometry files to be exchanged wth various CAD systems.

Shared Database Elements:

- **mathematical models**
- **graphic images**
- **bills of materials**
- **parts lists**
- **size, form**
- **locational dimensions**
- **tolerance specifications**
- **material specifications**

I. INTRODUCTION

5. CAM to CNC Interface

No standard protocol
Many proprietary designs
Historically high integration costs

Typically RS-232-C serial link
- **physical connection and voltage level specification only**

Protocol varies
- **data format, transmission mode, baud rate, parity, handshaking**

II. CAM REQUIREMENT ANALYSIS

1. Part Analysis
2. CNC Machine Tools
3. CAM Requirements
4. CAD System
5. Workforce

II. CAM REQUIREMENT ANALYSIS

1. Part Analysis

Part Description
- **Size and type of material**
- **Complexity of designs**
  - **tool changes**
  - **multiple fixtures**
- **Precision**

Quantity per Part Cycle
- **Number of parts/cycle**
- **Cycle time**
- **Machine usage**
- **Machine down-time**

Projection for Future
- **Expand business**
- **Increase quantity**
- **Increase precision**
- **Increase 3D parts**
- **Increase machine tool types (mill, lathe, EDM, grinder, laser, punch, CMM, ...)**

II. CAM REQUIREMENT ANALYSIS

2. CNC Machine Tools

Machine tool types & description
- variety of machines
- simultaneous axis operations
- unique requirements

Controllers
- variety of controllers
- availability of postprocessors
- unique requirements

Program transfer
- tape/disk
- direct connection (hard wired)
- local area network (LAN)

Future
- increased axis operations
- quantity of machines
- variety of machines

II. CAM REQUIREMENT ANALYSIS

3. CAM Requirements

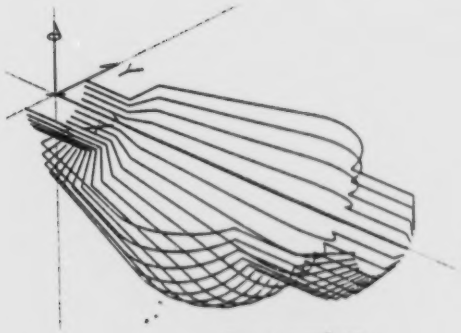
Review part complexity
- o **linear/circular interpolation**
- o **drilling patterns/arrays**
- o **pockets, pocket contours**
- o **pockets with islands/holes**
- o **part arrays**
- o **ruled surfaces**
- o **complex surfaces, multi-axis**
- o **global blend radii**

Macro capability
repeated sequences to save

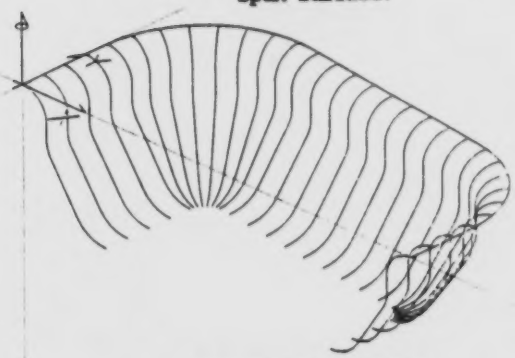
Parametric programming
family of parts, user variables

Communication/Translation files
IGES, DXF, CADL, others

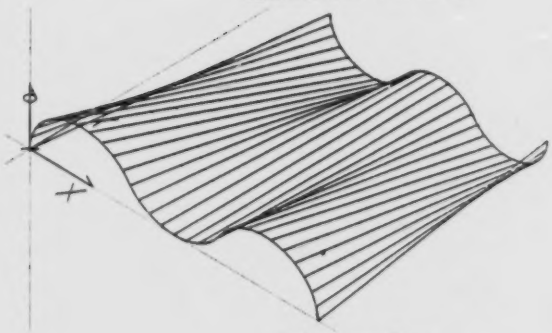
Operating systems
DOS, UNIX, MACINTOSH,...



Spun surface.



Translated surface.



Ruled surface.

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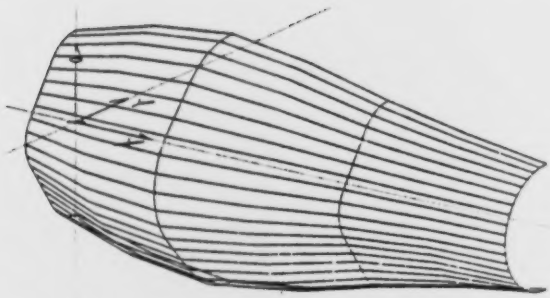
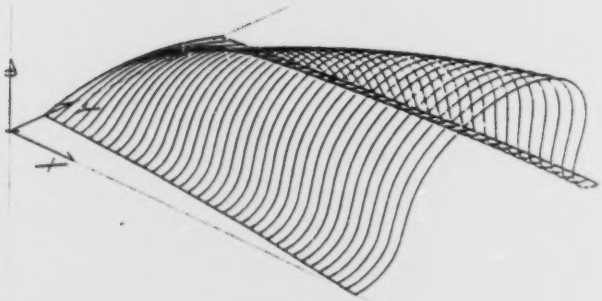


Lofted surface.



Form_Patch surface.

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II. CAM REQUIREMENT ANALYSIS

4. CAD System

In-House system(s)
- **design and drafting of parts**
- **detail drawings of parts**
- **CAD to be transfered to CAM**

Communication files
- **IGES, DXF, CADL, others**

Operating systems
- **DOS, UNIX, MACINTOSH,...**

Hardware
- **microprocessor**
- **display resolution and VRAM**
- **input devices (mouse, tablet,...)**
- **output devices (printer/plotter)**

Future

II. CAM REQUIREMENT ANALYSIS

5. Workforce

Engineering/Drafting environment
- o design engineers
- o product engineers
- o drafting

CAD knowledge requirements
- o CAD drafting/design functions
- o CAD drafting/update
- o CAD drafting/transfer

CAM knowledge requirements
- o CNC programmers
- o CAM programmers

Future workforce
- o train designers in machining
- o train CAM programmers to CAD
- o evaluate local workforce for availability of needed skills

III. CAM SOFTWARE EVALUATION

1. General Operation
2. System Types
3. Editing
4. CAD Interface
5. Post Processors
6. User Support
7. Cost Estimate
8. Sample Evaluation

III. CAM SOFTWARE EVALUATION

1. General Operations

Design to Manufacture

- **CAD to CAM vs. CAM only**
- **in-house CAD vs. vendor CAD**

Issues:

CAD layers
who designs?
who CAMs?

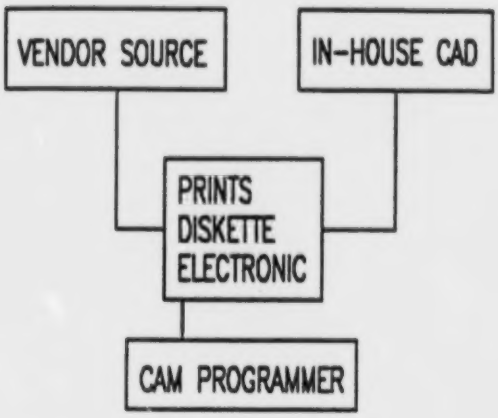
User Interface

- **words meaningful to CNC ops**
- **feedback of current state**
- **prompts**
- **on-line HELP**
- **"hot keys", function keys**
- **mixed input modes (keyboard and digitizer or mouse)**

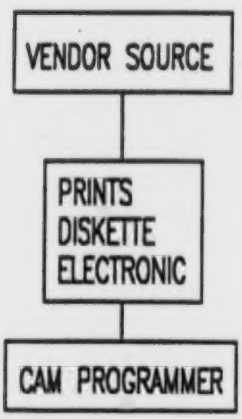
Performance

- **result time**
- **through-put time**

% CAD TO CAM



% CAM DIRECT



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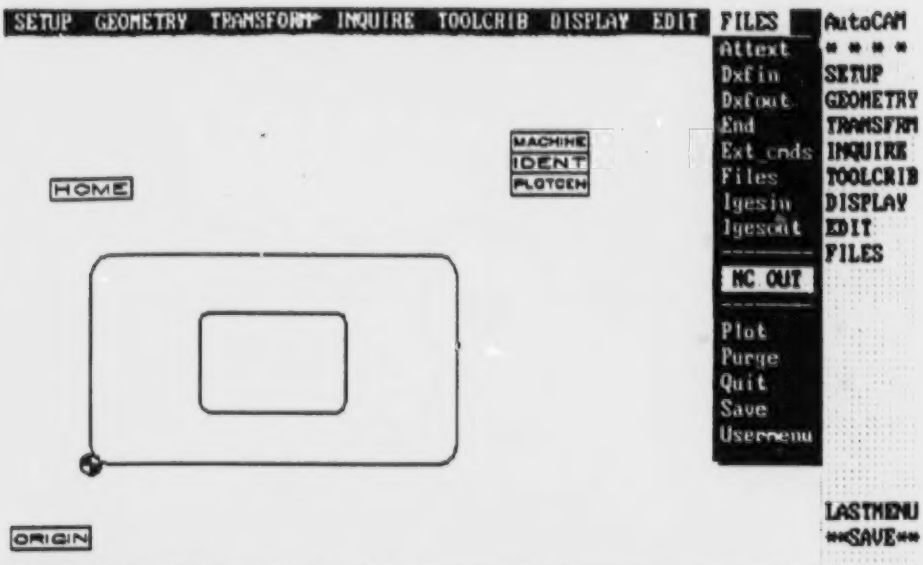

CAM MENU/CAD based Screen from AutoCAM CAD/CAM software.

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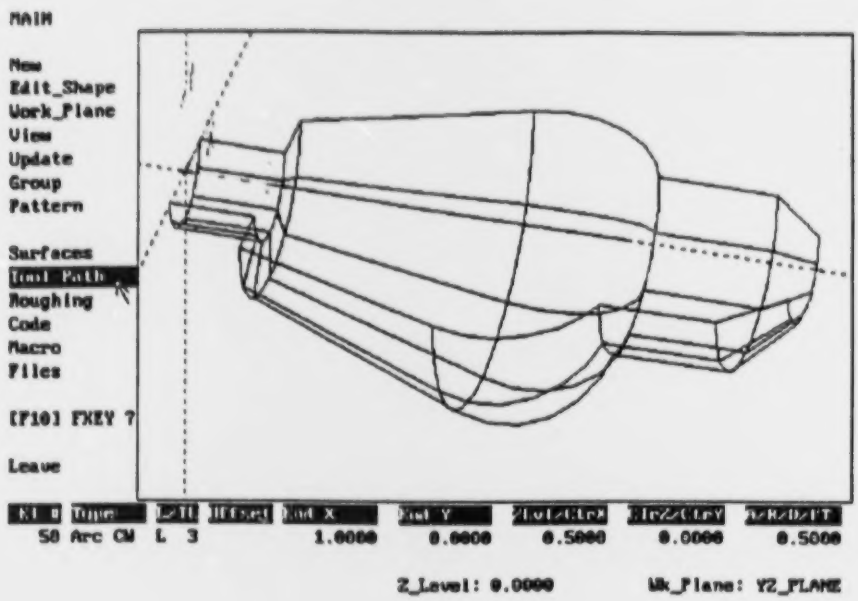

MENU screen from SmartCAM CAD/CAM software.

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PERFORMANCE

- INPUT -

SYSTEM A

INPUT	RESULTS
PICK TOOL	PROMPT FOR MACHINE
PICK MILL	PROMPT FOR TYPE
PICK CARBIDE	PROMPT FOR FLUTES
TYPE 4 FLUTE	PROMPT FOR DIAMETER
TYPE .500	PROMPT FOR XY FEED
TYPE 25 IPM	PROMPT FOR Z FEED
TYPE 10 IPM	PROMPT FOR COLOR
PICK COLOR	

SYSTEM B

INPUT	RESULTS
PICK TOOLCRIB	PROMPT FOR MACHINE
PICK MILL	PROMPT FOR MATERIAL
PICK MATERIAL	

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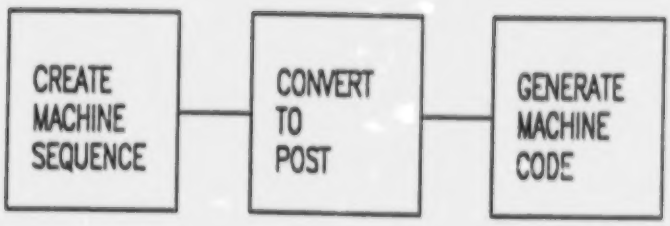
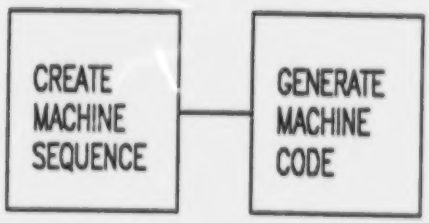
PERFORMANCE

- PROCESS -

SYSTEM A



SYSTEM B



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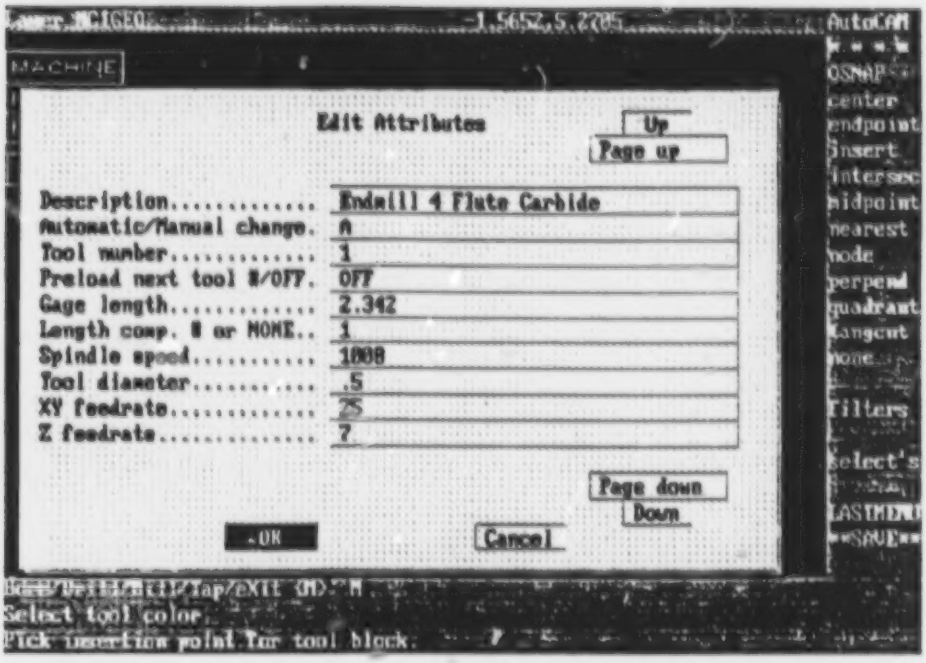

Tool parameter screen from AutoCAM software.

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```
  Cutter compensation in control = off
  Roll cutter around sharp corners
  Cutter compensation in computer = left  center
  Tool library: TOOLS.TL    Material: ALUM-S
  Tool number = 1    Diameter offset = 0    Length offset = 1
  Cutter diameter = 0.1250
  Amount of stock to leave = 0.0000
  Feedrate = 183.3500    Plunge rate = 91.6750    Spindle speed = 18335
  Coolant = off
  Rapid depth = 0.0000   Contour depth = 0.0000
  Starting sequence number = 100    Increment = 2    Program n. = 0
  No rotary axis
  Linear array: Nx, Ny = 1 1 Dx, Dy = 0.0000 0.0000
  Depth cuts: Rough: 1 cuts at 0.0000   Finish: 0 cuts at 0.0000
  Home position =  X0.0000 Y0.0000 Z0.0000
  Misc. real [1] = 0.0000    Misc. integer [1] = 0
  Mill in the XY plane
  Display: Tool (static,endpoints,run,delay = 0.00)   Toolpath
->Select this line when through setting parameters
```

Tool Parameter Screen from MasterCAM 3D software.

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III. CAM SOFTWARE EVALUATION

1. General Operations

CNC Parameter Specification
- o fixed order of entry
- o flexible order of entry
  - full screen edit
  - dialogue boxes

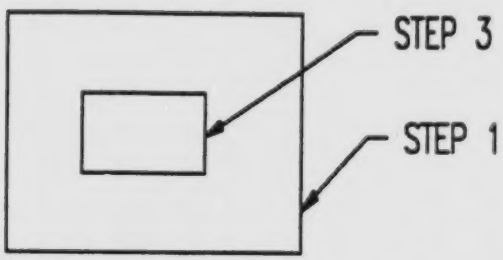
Logical Sequence
- o operation flow and prompts
- o remember user selections
- o customizable interface

Escape Procedures
- o controlled return or escape
- o accept/reject sequence
  - parameter screen
  - dialog box

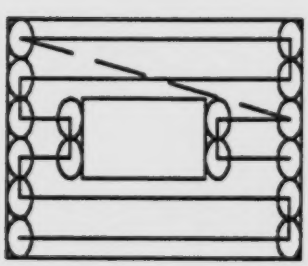
File Structure
- o remember user selections
- o create correct file .extensions

System Through-Put
- o function of user task request and hardware
- o upgrade hardware, customize

ESCAPE PROCEDURE



STEP 1 DIGITIZE BOUNDARY
2 SPECIFY ROUGH POCKET
3 DIGITIZE ISLAND
4 SPECIFY POCKET OFFSET LEFT
5 ESCAPE
6 SPECIFY POCKET OFFSET RIGHT
7 SAVE ROUTINE Y/N



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FILE STRUCTURE

SYSTEM A

STEP 1 START SOFTWARE
2 ENTER PROGRAM FILENAME
3 ROUTINE "A"
4 SAVE FILE
5 ENTER PROGRAM FILENAME
6 SHOW GRAPHIC TOOLPATH
7 ENTER PROGRAM FILENAME
8 POST
9 ENTER PROGRAM FILENAME
10 SAVE PROGRAM
11 ENTER PROGRAM FILENAME
12 ETC.

SYSTEM B

STEP 1 START SOFTWARE
2 ENTER PROGRAM FILENAME
3 CALL ANY ROUTINE
4 ETC

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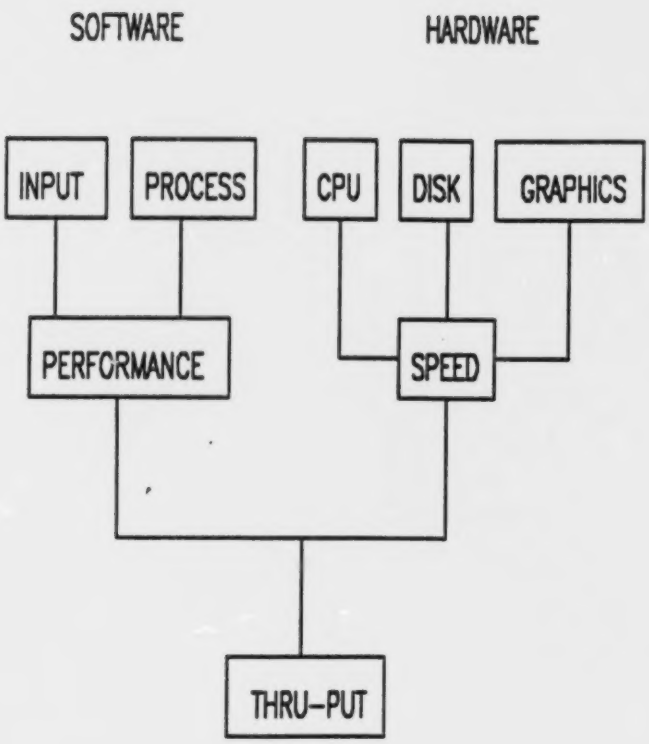
SYSTEM THRU-PUT



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III. CAM SOFTWARE EVALUATION

2. System Types

CAD based

- o familiar user interface
- o purchase CAD and CAM
- o external postprocessor
- o slower thru-put (database conversions)
- o easy manipulation of graphics
- o easy macro functions

CAM based

- o purchase only CAM
- o fast thru-put (one database)
- o possible CAD front-end
  - investigate drafting and detailing needs
- o CAD interfaces are prime concern (import/export)
- o internal postprocessor
- o limited graphics manipulation

CAM/CAD based

- o CAD front-end
- o fast thru-put (one database)
- o internal postprocessor
- o good graphics manipulation

III. CAM SOFTWARE EVALUATION

3. Editing

Machine Code

- machine tool controller
  - quick changes
- text editor
  - part of CAM system
  - outside of CAM system

Part Geometry

- edit or change a toolpath
- resequence process
- graphical change confirmation

Toolpath Parameters

- tool diameter, direction, offset

III. CAM SOFTWARE EVALUATION

4. CAD Interface

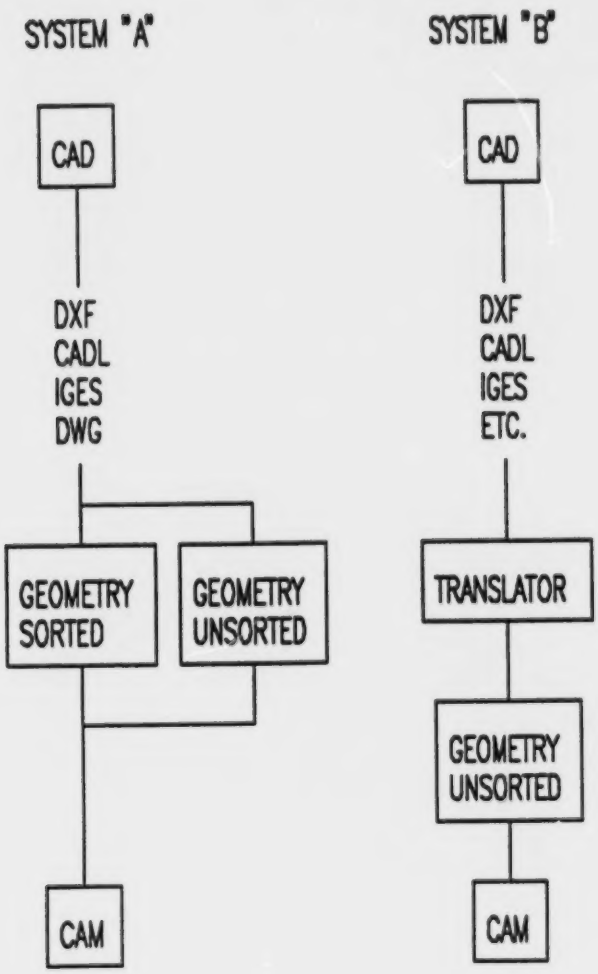
Direct

- **CAD to CAM on single layer**
- **Toolpaths defined in CAM**
  - **CAD designer not required**
  - **CAD software not required**
  - **CNC knowledge required**

Indirect

- **CAD operator alters layers to "fit" CAM system**
- **Must have access to CAD software or accept only jobs dedicated to CAM system**

CAD INTERFACE



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III. CAM SOFTWARE EVALUATION

5. Post Processors

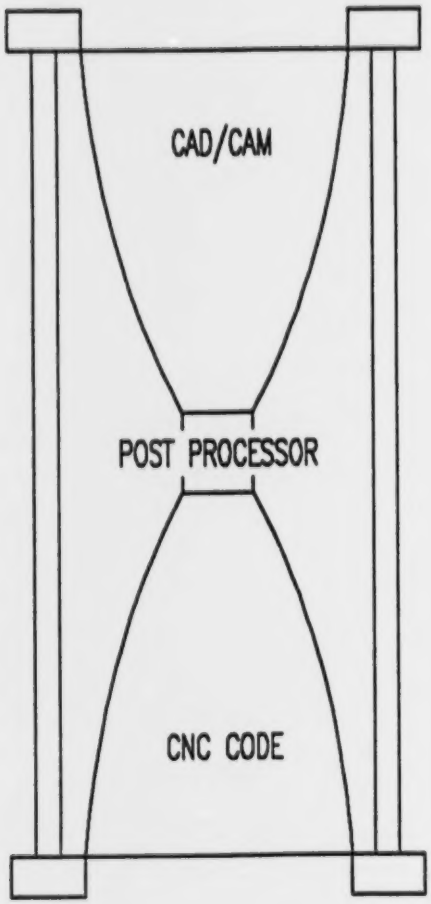
Generic

- o usually supplied
- o modifid by user to fit needs

Custom

- o proven for specific controller
- o purchase at $300 - $1500 per post
- o may get choice with system

POST PROCESSOR



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III. CAM SOFTWARE EVALUATION

6. User Support

Phone
- Software producer
- Authorized dealer

Local Representative
- Tech support
- Update awareness
- Update support

Training
- Software producer
- Authorized dealer

Bulletin Board System (BBS)
- Updates
- Utilities
- Postprocessors

III. CAM SOFTWARE EVALUATION

7. Cost Estimate

a. 2 1/2 D, CAD based system

CAD	$3,500	
CAM	$3,000	
GPOST	-	
Custom	_____	$1,500
	$6,500	$8,000

b. 2 1/2 D, CAM based system

CAM	$7,000	
GPOST	-	
Custom	_____	$1,000
	$7,000	$8,000

c. 2 1/2 D, CAD/CAM system

System	$6,000	
GPOST	-	
Custom	_____	$ 600
	$6,000	$6,600

III. CAM SOFTWARE EVALUATION

8. Evaluation

a. Services and support

b. Quality

c. Delivery and installation

d. Initial costs

e. Ongoing costs

EVALUATION CHART

	SYS A	SYS B	SYS C
DESIGN TO MANUFACTURE			
INTERFACE			
PERFORMANCE			
CNC PARAMETERS			
LOGICAL SEQUENCE			
ESCAPE PROCEDURE			
FILE STRUCTURE			
SYSTEM THRU-PUT			
CAD BASED			
CAM BASED			
CAM/CAD BASED			
EDIT CODE			
EDIT GEOMETRY			
EDIT PARAMETERS			
DIRECT CAD INTERFACE			
INDIRECT CAD INTERFACE			
GENERIC POST			
CUSTOM POST			
USER SUPPORT			
COST W/O CAD			
CAD ADDL. COST			
POINT TOTALS			
COST			

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The numeric evaluation shown below is based on a scale from 1-5 with the number 5 being the highest rating. Each category expresses an inclusion/consideration based on Ease of Use, Functionality and Reliability.

Evaluation category	System A	System B	System C
General operation			
- Design to Manufacture	4	3	4
- Interface	4	4	3
- Performance	5	4	3
- CNC Parameters	4	3	3
- Logical sequence	5	5	3
- Escape procedure	5	5	4
- File Structure	4	5	3
- System Thru-put	5	5	3
System type			
- CAD based -	-	-	3
- CAM based -	4	4	-
Editing			
- Machine Code	4	4	4
- Part Geometry	3	5	3
- Toolpath Parms	5	5	2
CAD interface			
- Direct	5	-	4
- In-Direct	-	4	-
Post Processor			
- Generic	3	3	3
- Custom	4	4	4
User Support			
- Phone	3	2	4
- Local Rep.	-	-	-
- BBS	-	-	4
Cost est.			
- Single post sys.	4	3	5
- Cad required	1	1	-
Totals (example)	72	69	62
Cost	$10,000	$12,000	9,500

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IV. SmartCAM

1. Capabilities
2. Available Functions
3. General Method of Use
4. User Interface
5. Preparing to Write a Program
6. Process Modeling
7. Generating CNC Code
8. Editing Code
9. Communications

IV. SmartCAM

1. Capabilities

Use existing CAD files or create new model

Built in speeds & feeds calculations

Solves creation and editing of geometry

Creates roughing passes for geometry profiles

Internal postprocessor, "code generator"

IV. SmartCAM

2. Available Functions

Job Plan	**machine, tool, model layer info**
Applications	**mill, lathe, punch, EDM**
Edit Plus	**ASCII text editor**
Communicate	**RS-232 format**
Design	**Access CAD system from SmartCAM**
CAM Connection	**Convert CAM files to SmartCAM**
Machine Define	**Customize postprocessors**

IV. SmartCAM

3. General Method of Use

a. Create/modify Job Plan file

b. Select Application

c. Construct geometry

d. Insert machining operations

e. Show path to review operations

f. Generate code

g. Download code to machine

h. Verify

IV. SmartCAM

4. User Interface

Graphical User Interface (GUI)

Mouse or Keyboard input

Workplace Environment

- **top menu bar**
- **workbench**
- **toolbox**
- **list view**
- **contol panel/dialogue box**
- **graphic window**

Hot Keys

Screen Layout

Exercise 1: Existing Model

Hot Keys

SmartCAM Hot Keys are function keys that carry out or set a mode of operation when you press them. SmartCAM provides the following Hot Keys:

Hot Key	What It Does
[F1]	Enables you to input a value or coordinate. Displays the File Select Dialogue Box where appropriate.
[F2]	Turns Snap On or Off in the Read-out Line.
[F3]	Pulls down the Work_Plane Menu.
[F4]	Redisplays the last dialogue box.
[F5]	Pulls down the View Menu.
[F6]	Pulls down the Utility Menu.
[F7]	Displays data for a selected element (works the same as Element_Data in the View Menu).
[F8]	Redraws the screen (works the same as Redraw in the View Menu).
[Esc]+[Letter]	Selects a modeling tool in a toolbox. [Letter] should be the first letter of the modeling tool you want. Press [Esc] and the [Letter] key at the same time.
[Esc][Esc]	Returns you to the File Menu from anywhere in SmartCAM. Press [Esc] twice in sequence.
[Alt]+[Letter]	Selects a pull-down menu from the menu bar. [Letter] should be the first letter of the pull-down menu you want to display. Press [Alt] and the [Letter] key at the same time.
[Alt]+[1,2, *or* 3]	Opens the toolbox preceded by the selected number on the workbench. Press [Alt] and the number key at the same time.
[Tab]	Advances to the next control panel field.
[Shift]+[Tab]	Moves back one control panel field.
[Alt]+[F8]	Redraws dialogue boxes and control panels.
Show_Path Keys	The following keys are operational in Show_Path: [Esc][Esc] Quits Show_Path. [Esc] Stops Show_Path so that you can change Show_Path speed. [S] Starts Show_Path.
[Alt]+[H]	Provides help for the current menu item, toolbox, control panel, dialogue box or modeling tool.
[Home]	Positions to the top of a list. Useful in Insert position.
[End]	Positions to the bottom of a list. Useful in Insert position.

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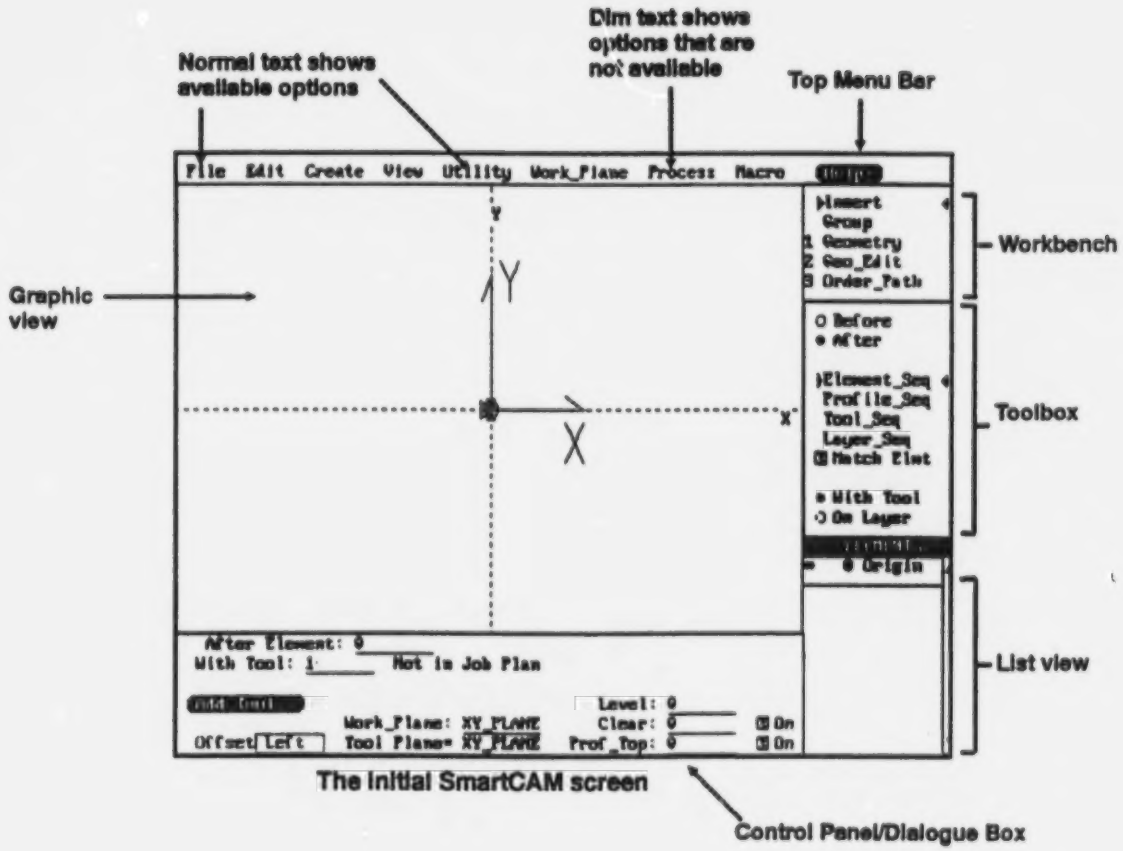

The Initial SmartCAM screen

Control Panel/Dialogue Box

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IV. SmartCAM

5. Preparing to Write a Program

Communicate information about the part to be machined, the tooling, and the setup to the CNC machine operator.

a. Plan the setup

b. Plan the tool path

c. Select tools

d. Select speeds and feeds

IV. SmartCAM

5. Preparing to Write a Program

Job Plan

Operation Information

1. Machine type
2. Machine
3. Drawing number
4. Part number
5. Operation number
6. Material blank
7. Special notes

Tool Data

1. Tool number or station no.
2. Tool type
3. Tool ID number (optional)
4. Offsets
5. Speed and Feed

Exercise 2: Existing Job Plan

IV. SmartCAM

6. Process Modeling

Milling (2 1/2 D)

- **Geometry creation features**
- **Geometry edit features**
- **Verification features**

Exercise 3: Free form geometry

Exercise 4: Profile geometry

IV. SmartCAM

7. Generating CNC Code

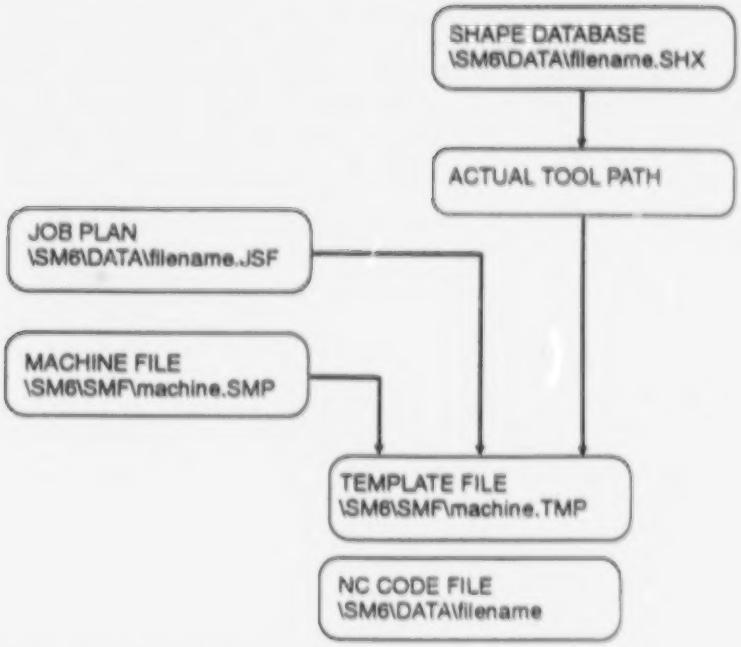
Job Plan information

Shape Database

Machine File

Template File

Exercise 5: Generate Code



Files used for Code Generation

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IV. SmartCAM

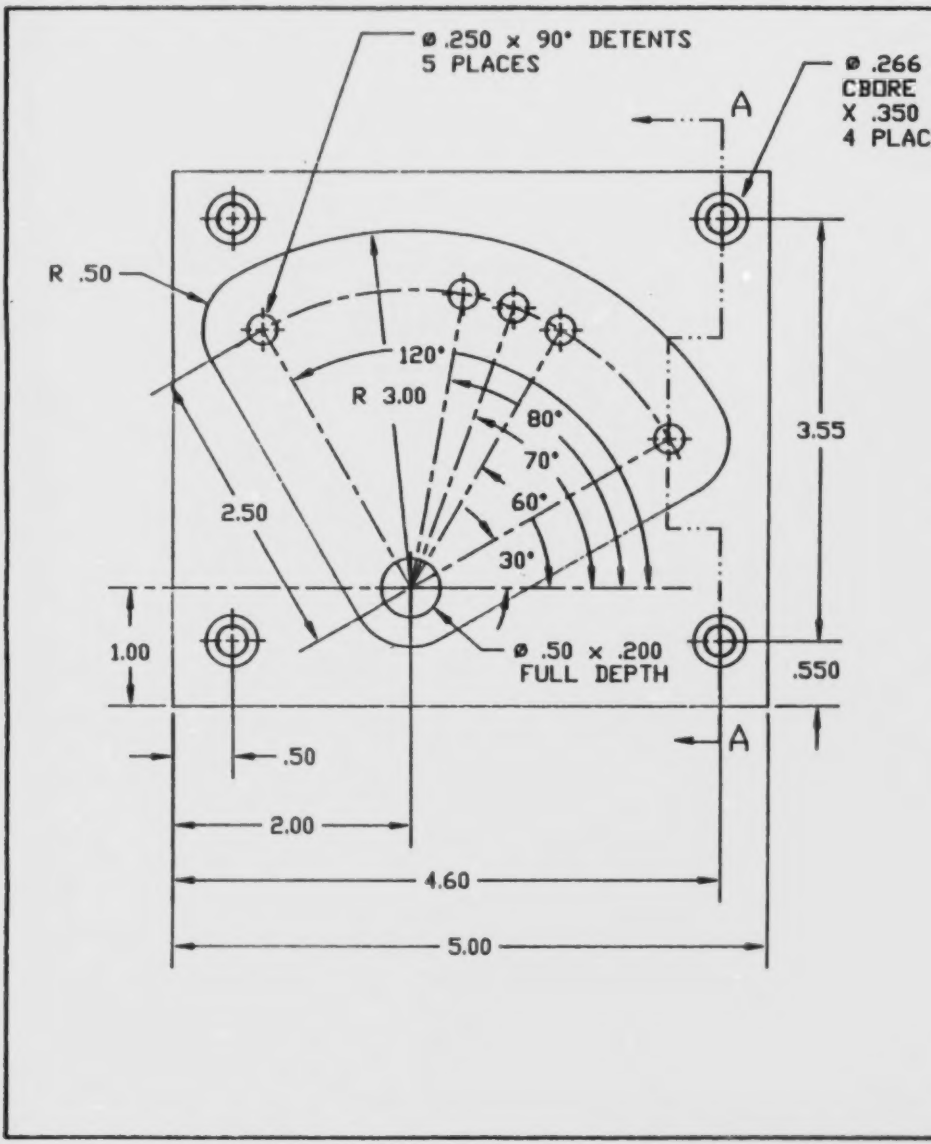
8. Editing Code

Edit Plus text editor

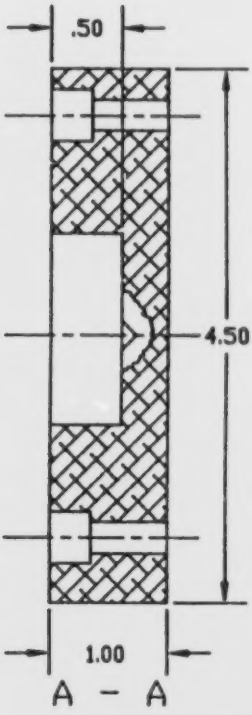
Exercise 6:

Generate code
Modify job plan
Generate code again
View both files
Note differences

APPENDIX A: PART DRAWINGS

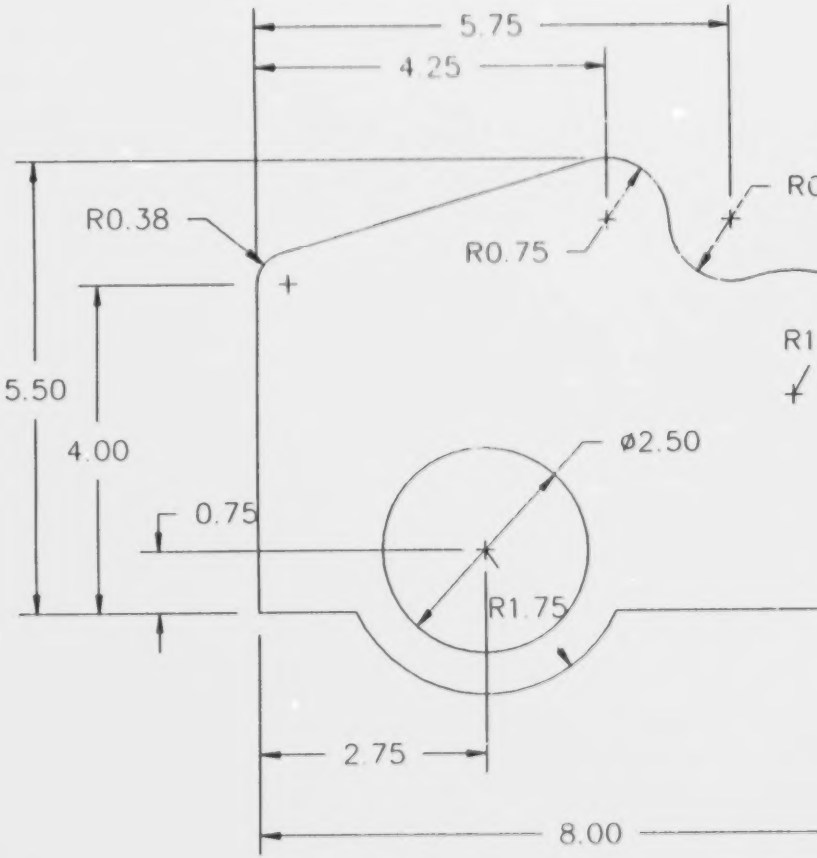

ø .250 x 90° DETENTS
5 PLACES
ø .266
CBORE
X .350
4 PLAC
A
R .50
120°
R 3.00
80°
70°
60°
30°
2.50
3.55
1.00
ø .50 x .200
FULL DEPTH
.550
A
.50
2.00
4.60
5.00

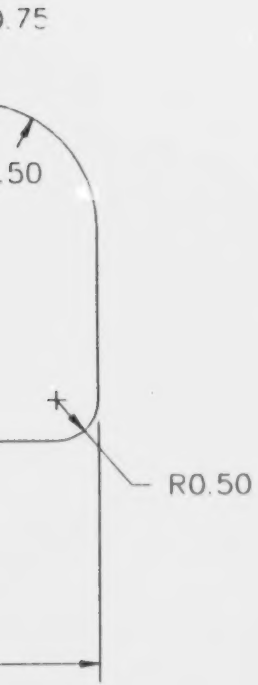
THRU
Ø.4375
DP.
ES



NOT FOR DRILLED HOLES INCHES TOLERANCES UNLESS OTHERWISE SPECIFIED	
1 PLACE DIMS.	± .1
2 PLACE DIMS.	± .01
3 PLACE DIMS.	± .005
ANGULAR	± 1°
DO NOT SCALE	

MC-1234-A	SHIFT PLATE
PART NUMBER	PART NAME
Point Control Co. (503)344-4470	
DRAWN BY: G. WITTLOCK	MATERIAL: ALUMINUM
SCALE: NONE	DATE: 7-24-91


5.75
4.25
R0.38
R0.75
5.50
4.00
0.75
ø2.50
R1.75
2.75
8.00



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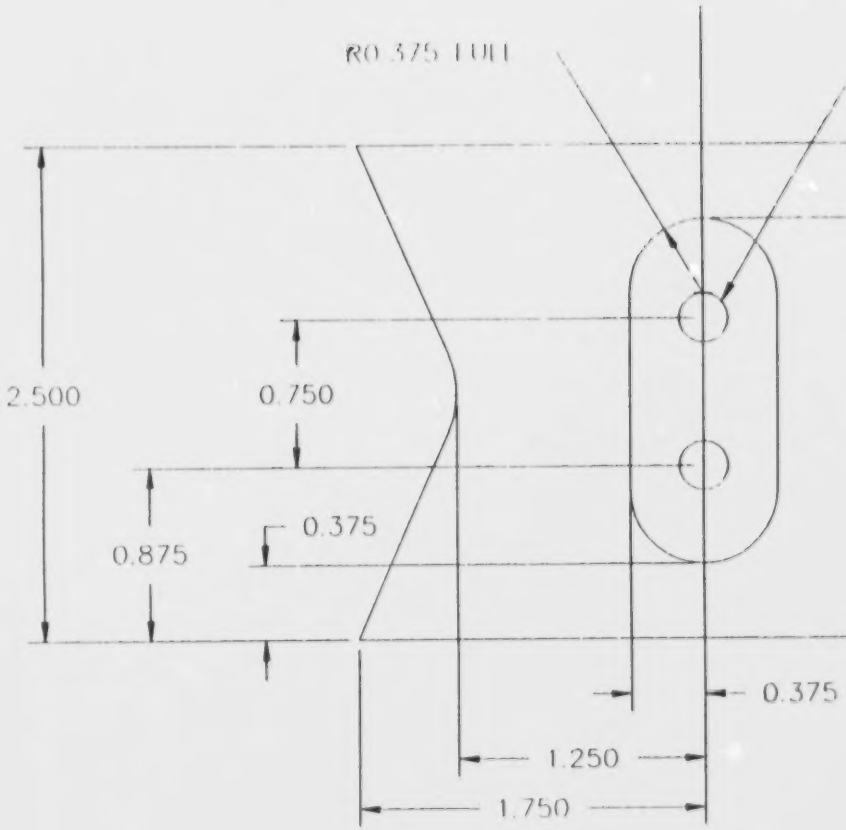
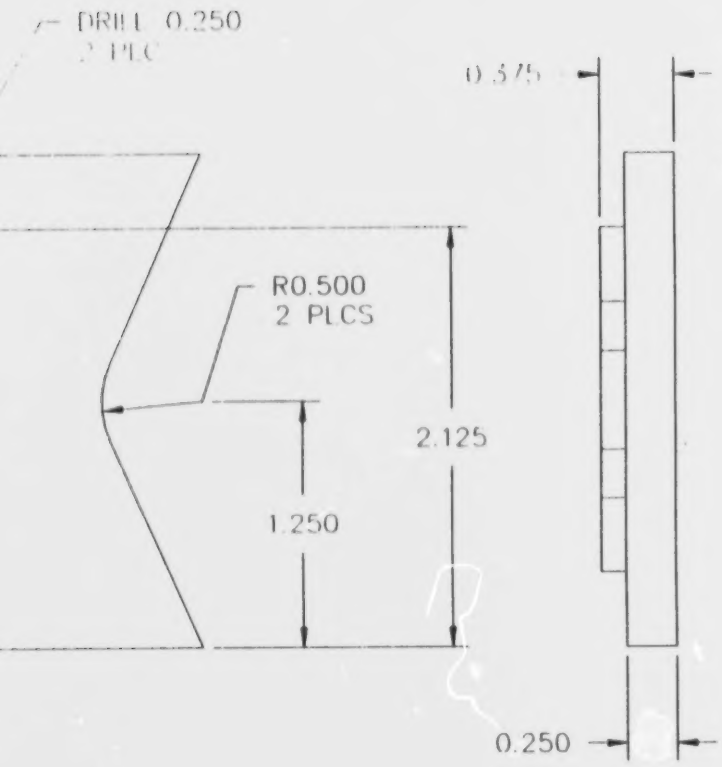
BEGINING EXAMPLE
MILL #1


R0.375 TUIT
2.500
0.750
0.875
0.375
0.375
1.250
1.750



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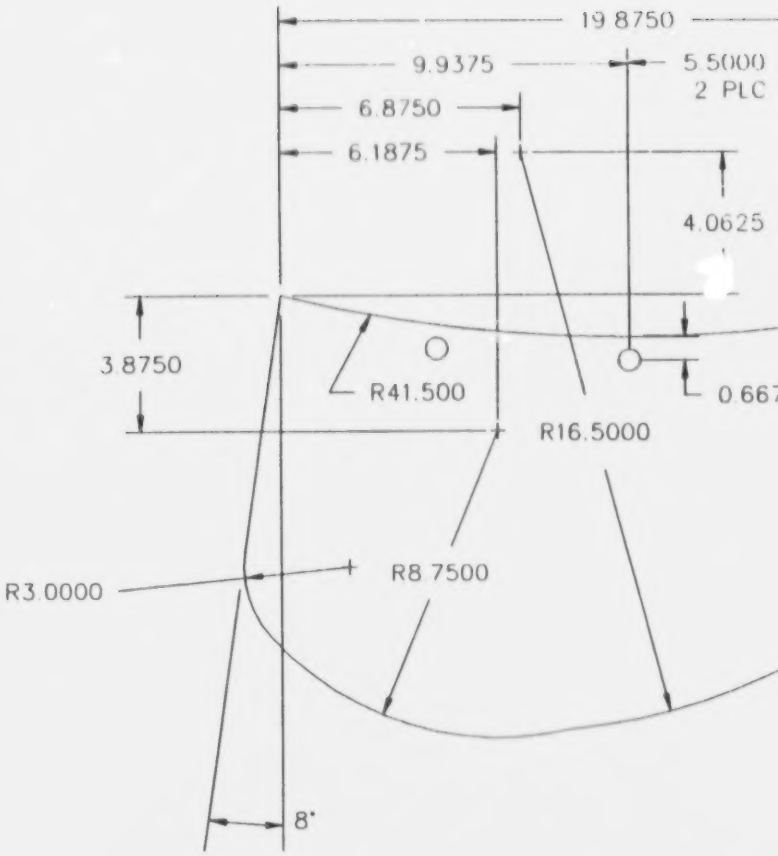
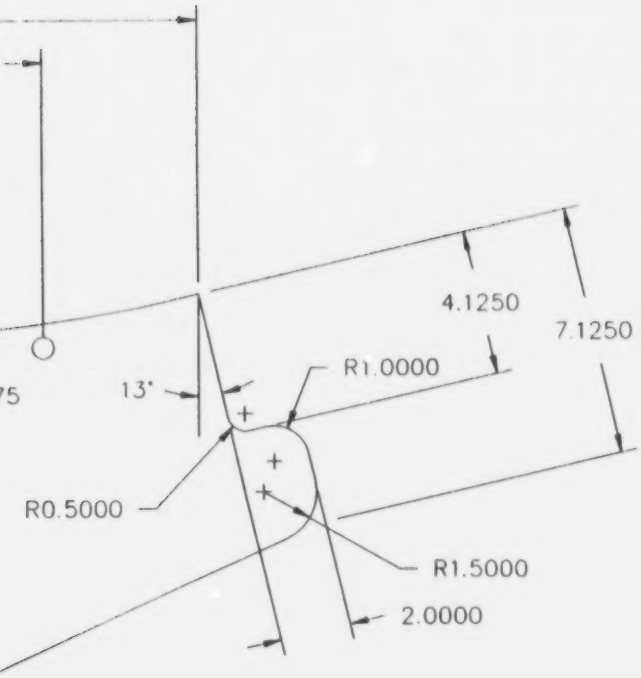
BEGINING EXAMPLE
MILL #2


19.8750
9.9375
5.5000
2 PLC
6.8750
6.1875
4.0625
3.8750
R41.500
0.667
R16.5000
R3.0000
R8.7500
8°



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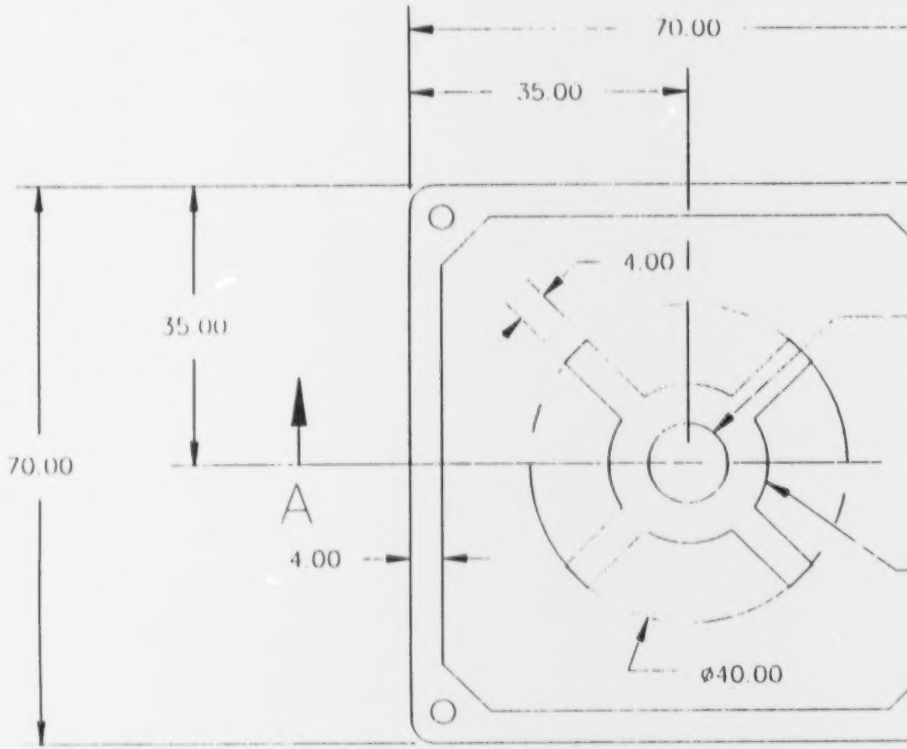
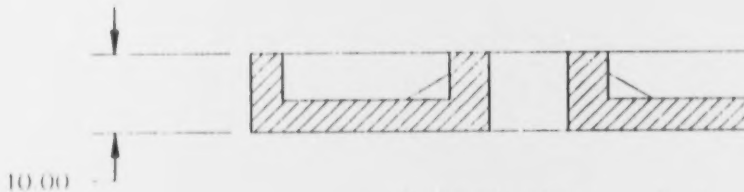
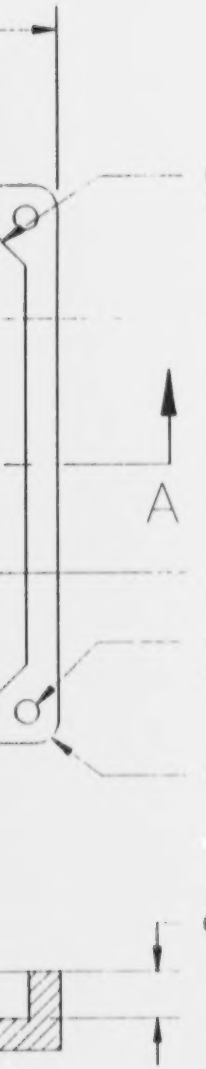
BEGINING EXAMPLE
PROFILER #2





65

SECTION AA



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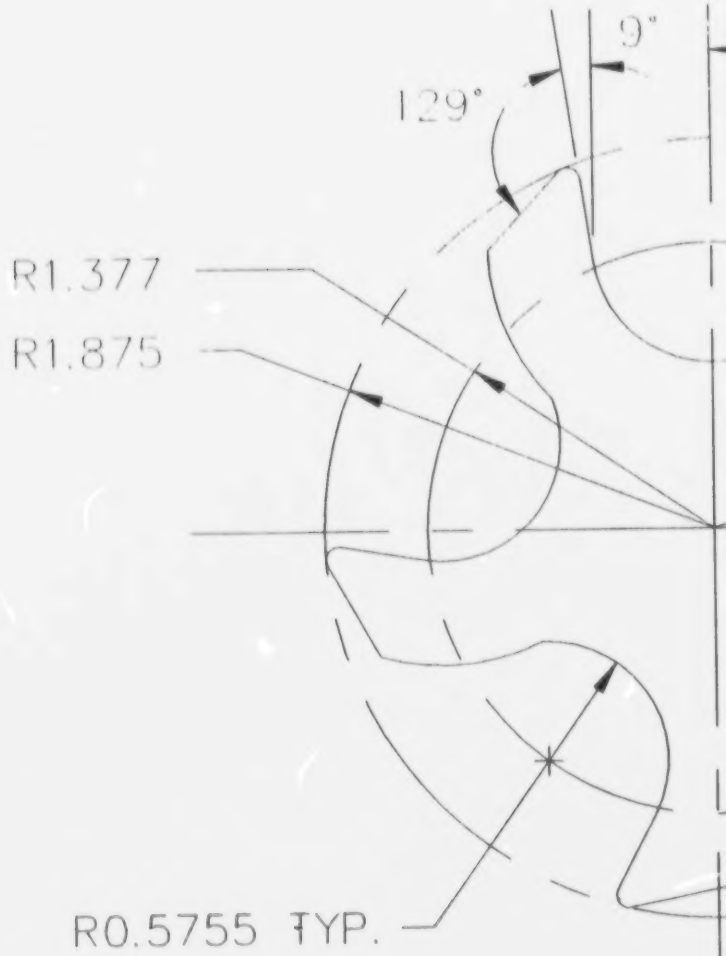
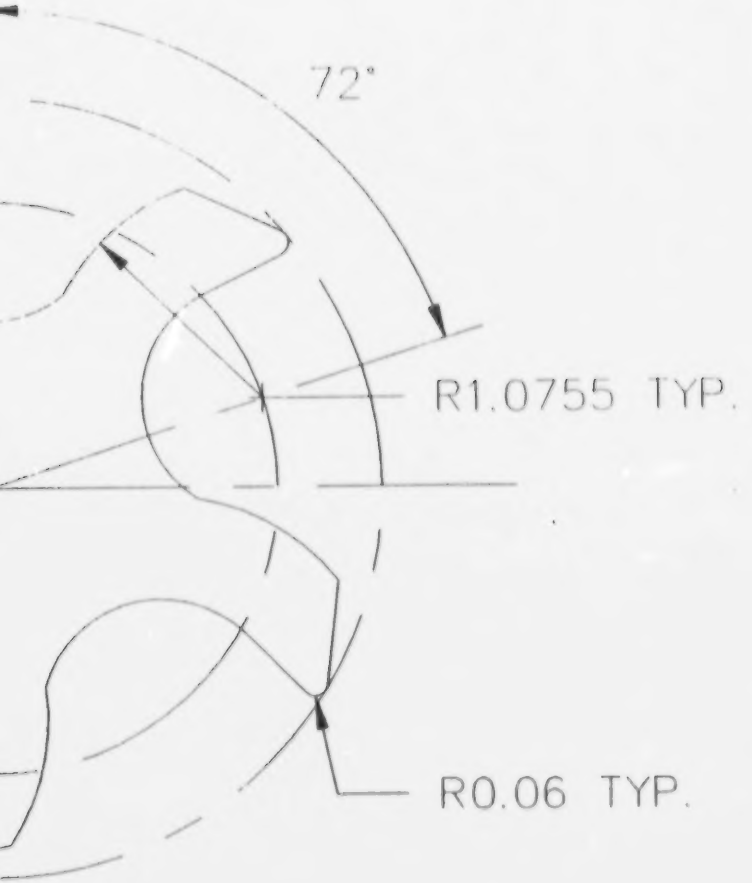
ADVANCED EXAMPLE
MILL #1


9°
129°
R1.377
R1.875
R0.5755 TYP.



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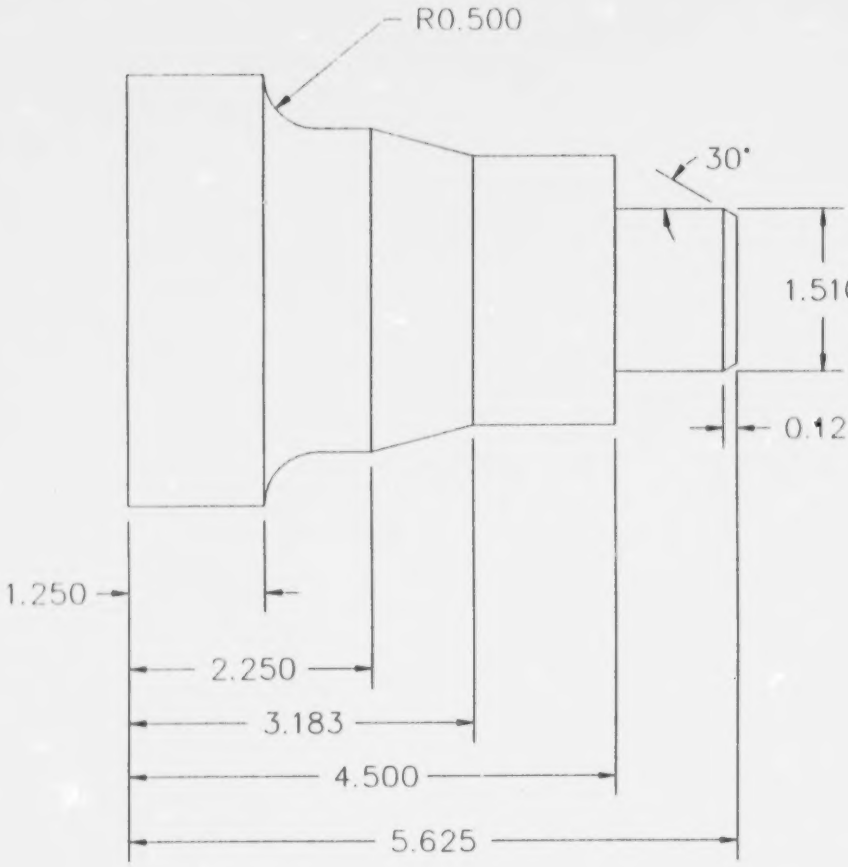
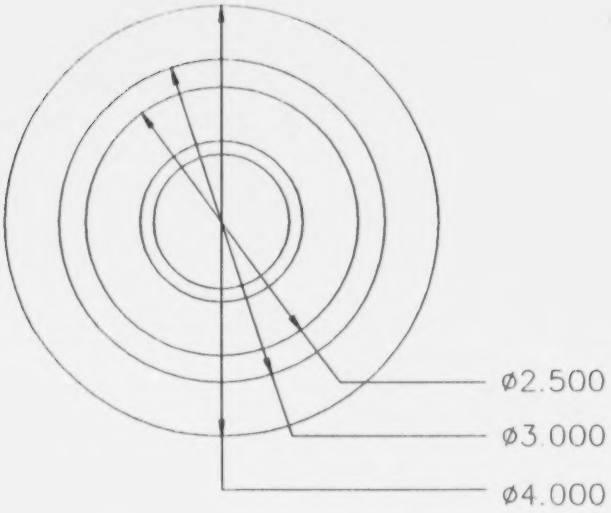
ADVANCED EXAMPLE
WIRE ITEM #1


R0.500
30°
1.250
2.250
3.183
4.500
5.625



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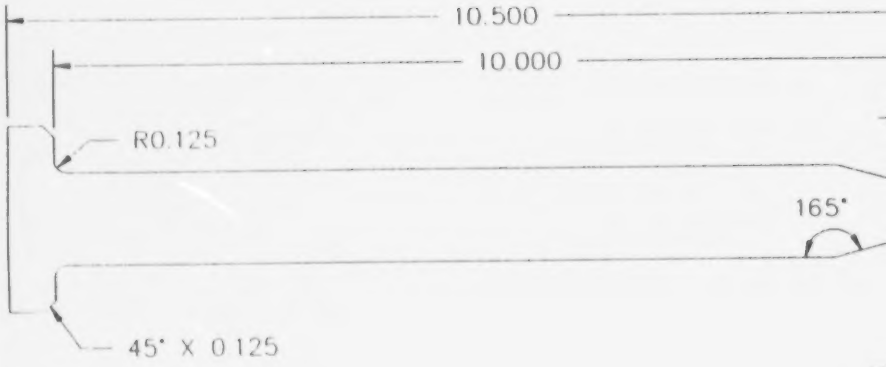
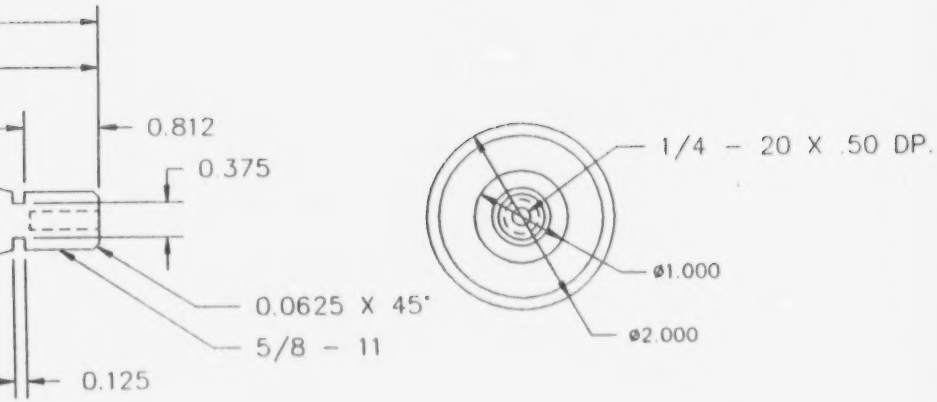
BEGINING EXAMPLE
LATHE #1


10.500
10.000
R0.125
165°
45° X 0.125



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ADVANCED EXAMPLE
PATH #2

APPENDIX B: HOT KEYS

Hot Keys

SmartCAM Hot Keys are function keys that carry out or set a mode of operation when you press them. SmartCAM provides the following Hot Keys:

Hot Key	What It Does
[F1]	Enables you to input a value or coordinate. Displays the File Select Dialogue Box where appropriate.
[F2]	Turns Snap On or Off in the Read-out Line.
[F3]	Pulls down the Work_Plane Menu.
[F4]	Redisplays the last dialogue box.
[F5]	Pulls down the View Menu.
[F6]	Pulls down the Utility Menu.
[F7]	Displays data for a selected element (works the same as Element_Data in the View Menu).
[F8]	Redraws the screen (works the same as Redraw in the View Menu).
[Esc]+[Letter]	Selects a modeling tool in a toolbox. [Letter] should be the first letter of the modeling tool you want. Press [Esc] and the [Letter] key at the same time.
[Esc][Esc]	Returns you to the File Menu from anywhere in SmartCAM. Press [Esc] twice in sequence.
[Alt]+[Letter]	Selects a pull-down menu from the menu bar. [Letter] should be the first letter of the pull-down menu you want to display. Press [Alt] and the [Letter] key at the same time.
[Alt]+[1,2, *or* 3]	Opens the toolbox preceded by the selected number on the workbench. Press [Alt] and the number key at the same time.
[Tab]	Advances to the next control panel field.
[Shift]+[Tab]	Moves back one control panel field.
[Alt]+[F8]	Redraws dialogue boxes and control panels.
Show_Path Keys	The following keys are operational in Show_Path: [Esc][Esc] Quits Show_Path. [Esc] Stops Show_Path so that you can change Show_Path speed. [S] Starts Show_Path.
[Alt]+[H]	Provides help for the current menu item, toolbox, control panel, dialogue box or modeling tool.
[Home]	Positions to the top of a list. Useful in Insert position.
[End]	Positions to the bottom of a list. Useful in Insert position.

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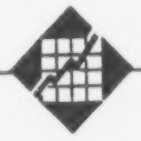
PLC BASICS

Developed by
Gerard Insolia

Center for Business and Industry
Northampton Community College
3835 Green Pond Road
Bethlehem, PA 18017-7599



PLC BASICS SEMINAR OUTLINE

1. WELCOME AND PERSONAL INTRODUCTION

2. WHAT IS A PLC?

3. HISTORY OF THE PLC
   - A. ORIGIN
   - B. ORIGINAL INTENT OF THE PLC
   - C. FLEXIBILITY AND SIMPLICITY
   - D. ARE PLC'S COST EFFECTIVE?
   - E. WHEN, WHERE, HOW AND WHY

4. BASIC COMPONENTS OF A PLC
   - A. CENTRAL PROCESSING UNIT
   - B. POWER SUPPLY
   - C. I/O SYSTEM

5. LOGICAL FORMAT
   - A. HAND LOADERS, CRT'S, DATA LOADERS AND PC'S/PC SOFT WARE
   - B. LADDER LOGIC
   - C. STATEMENT LOGIC
   - D. STRUCTURED PROGRAMMING

6. REVIEW OF BASIC CONTROL CIRCUIT DIAGRAMS
   - A. RELAY LOGIC EXAMPLES
   - B. PLC WIRING DIAGRAM EXAMPLE
   - C. PLC LADDER LOGIC EXAMPLES
   - D. PLC STATEMENT LIST LOGIC EXAMPLES

7. EMERGENCY STOP AND SAFETY CIRCUIT CONTROL

8. ELECTRICAL NOISE PROBLEMS AND POTENTIAL SOLUTIONS

9. PLC APPLICATIONS AND EXAMPLES

10. QUESTION AND ANSWER

NOTES:

OVERHEAD SLIDES WILL BE UTILIZED

UTILIZE HANDOUTS SUCH AS THE WESTINGHOUSE PLC ARTICLES AND THE PLC EXPERT EXAM

INTERACTION WITH THE CLASS WILL BE ENCOURAGED

CAPABILITIES

What is a PLC?

Basics:

- I/O Interfaces
- Memory
- Processor
- Programming Language & Device
- Power Supply
- Housings

CAPABILITIES (cont)

How has the PLC evolved?

Relay Replacement

Arithmetic Operations

Interface with Analytical Instrumentation
- o obtain operation results
- o measure tolerances
- o perform calculations
- o take corrective action

Analog Control Functions

Indicator Lights

Self-Diagnostics
- o power indicators
- o transmission faults

Communications
- o Peripherals
- o Other PLCs
- o Distributed Control

CAPABILITIES (cont)

PLCs vs Other Types of Controls

PLC vs. Computer

- PLC designed to communicate with process directly
- Familiar programming techniques for a plant technician or electrician
- PLCs designed for industrial environment

PLC vs Relays

- Versatility and flexibility
- Simplified field wiring
- Space

SELECTION CONSIDERATIONS

System Attributes

1. I/O Requirements

- o Number of I/O points

- o Types of I/O
  - Discrete or analog
  - AC or DC — AC: 24V, 115V, 230V
    DC: 5V, 12-30V

- o Special Features
  - High speed inputs
  - Servo drive module
  - Thermocouple module
  - Communications

- o Location of I/O
  - Distributed control
  - Remote I/O

SELECTION CONSIDERATIONS (cont)

2. Memory Requirements

- o Type
- o Capacity
- o Allocation
  - program area
  - executive programs
  - data table area

3. Programming Requirements

- o Instruction Set

4. Peripheral Requirements

- o Programmer
- o Printer
- o Modem
- o Computer

SELECTION CONSIDERATIONS

How Cost-Effective are PLCs?

Factors

- Purchase price
- Installation costs
- Throughput
- Machine system safety
- Versatility
- Downtime and repair costs
- System power consumption
- Expandability
- Longevity

APPLICATIONS

1. Bulk Material Handling

Fiberglass production at PPG Industries

System Description

- **Raw ingredients weighed, mixed, transported**
- **Batch fed continuously into furnaces**

Control Strategy

- **Hierarchical control system**
- **3 independent subsystems**
- **Semi- or fully- automatic operation**

1. Bulk Material Handling (cont)

Fiberglass production at PPG Industries

Implementation

- Activated incrementally
- Distributed control with 20 PLCs
- Supervisory PLC coordinates operation and controls batch system
- Redundant precossor and power supply
- Process computer performs monitoring, alarming, logging functions

Results

- System replaces two operators

2. Controlling Heat Treating Ovens

General Electric Company

System Description

- Rail car loaded with six 30,000 pound ingots is run into the oven
- Oven brought up to Temp1 and maintained
- Temp dropped at controlled rate until Temp2
- Cycle repeated four times

Control Strategy

- Oven divided into three segments, six zones
- 1 sensor for each segment
- 2 secondary sensors for each segment

2. Controlling Heat Treating Ovens

General Electric Company

Implementation

- Combustors fueled from motor driven valves
- 2-speed circulating fans distribute heat
- One PLC controls oven temp, valves, fans
- PID control used to minimize temperature fluctuations

Results

- Large energy savings due to accurate control

3. Packaging Food in Glass

FLOE Inc.

System Description

- Glass containers are fed, cleaned, filled, and capped
- Containers are queued if necessary
- Containers are labeled, assembled into cases, and palletized

Control Strategy

- Variety of inputs suited to particular tasks
- Control conveyor speed for better filling
- Active accumulator to control supply to labeler

3. Packaging Food in Glass

FLOE Inc.

Implementation

- **Proximity, photocell, and microswitch inputs**
- **All motor control sequenced by the PLC**
- **Accumulator conveyor driven forward or reverse, based on labeler load**
- **PLC counts each jar, cap, and label. Records time and count of all line malfunctions.**
- **Report generated showing efficiency of each piece of equipment on the line**

Results

- **Total line efficiency monitoring aids maintenance management**
- **Equipment replacement simplified**

APPLICATIONS

4. Energy management

Seaboard Energy Systems, Inc.

Reducing electrical consumption and peak demand

- **Monitor electric meter to pinpoint rising consumption**
- **PLC shuts down predetermined equipment to avoid peak charges**

Managing chillers

- **Monitor chilled water in the loop, ambient temp, discharge and return temp, and chiller load**
- **Control difference between discharge and return water temps, units on/off line**

4. Energy management (cont)

Seaboard Energy Systems, Inc.

Controlling boilers

- Monitor steam flow and steam pressure
- Increase/decrease the fuel flow as steam pressure drops/increases

Controlling outside dampers

- Monitor outside air temp and return air temp
- Control amount of fresh air mixed with return air to be heated or cooled
- Use motorized damper controls to open/close the dampers as temperature changes during the day

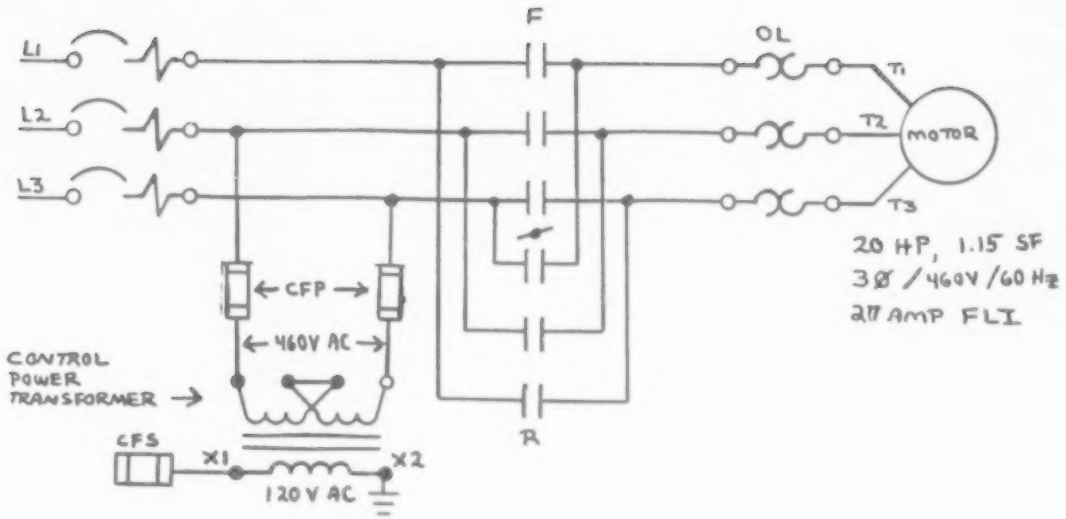
Results

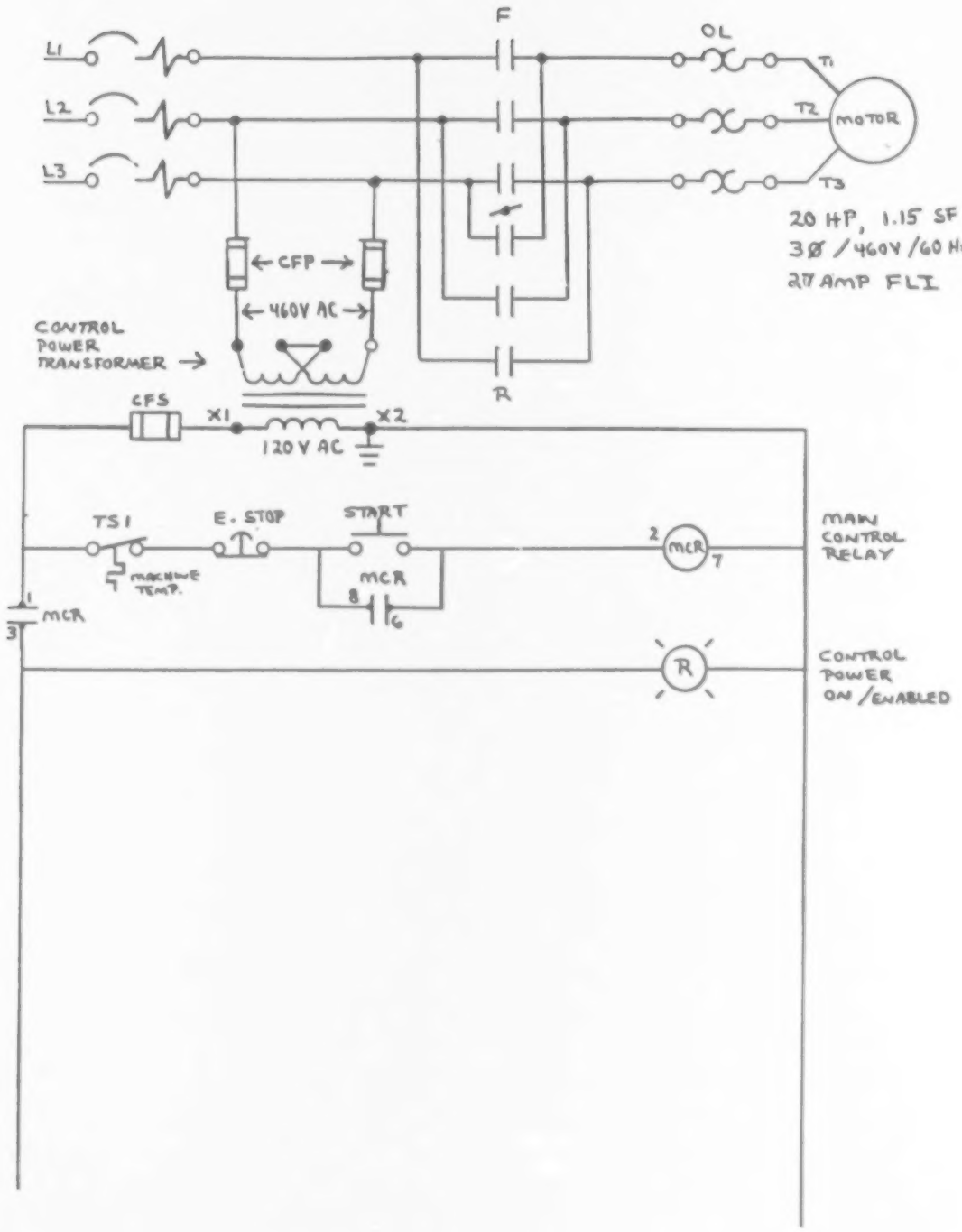
- 10 to 20 percent reduction in energy consumption and costs

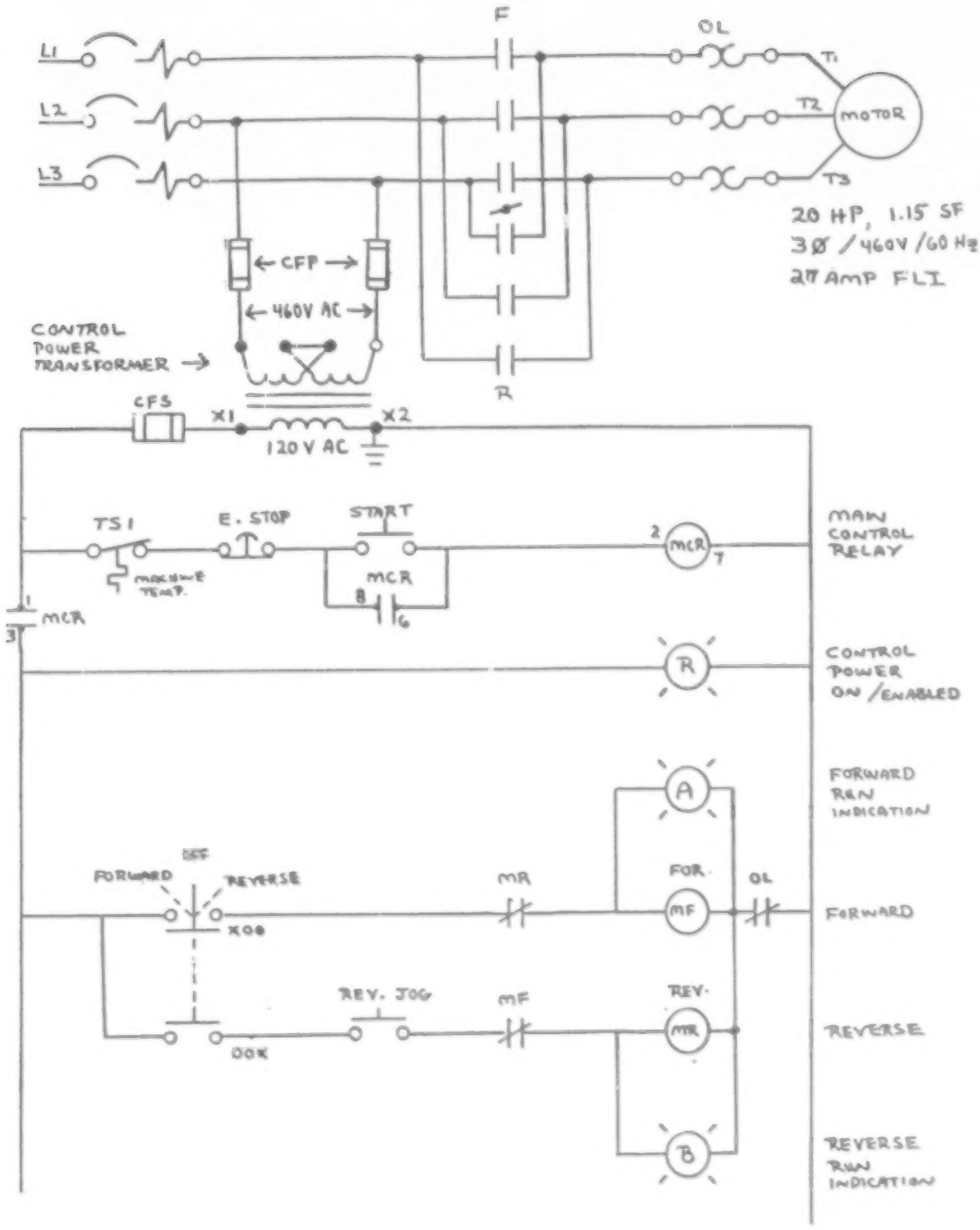
APPLICATIONS

Industry Breakdown

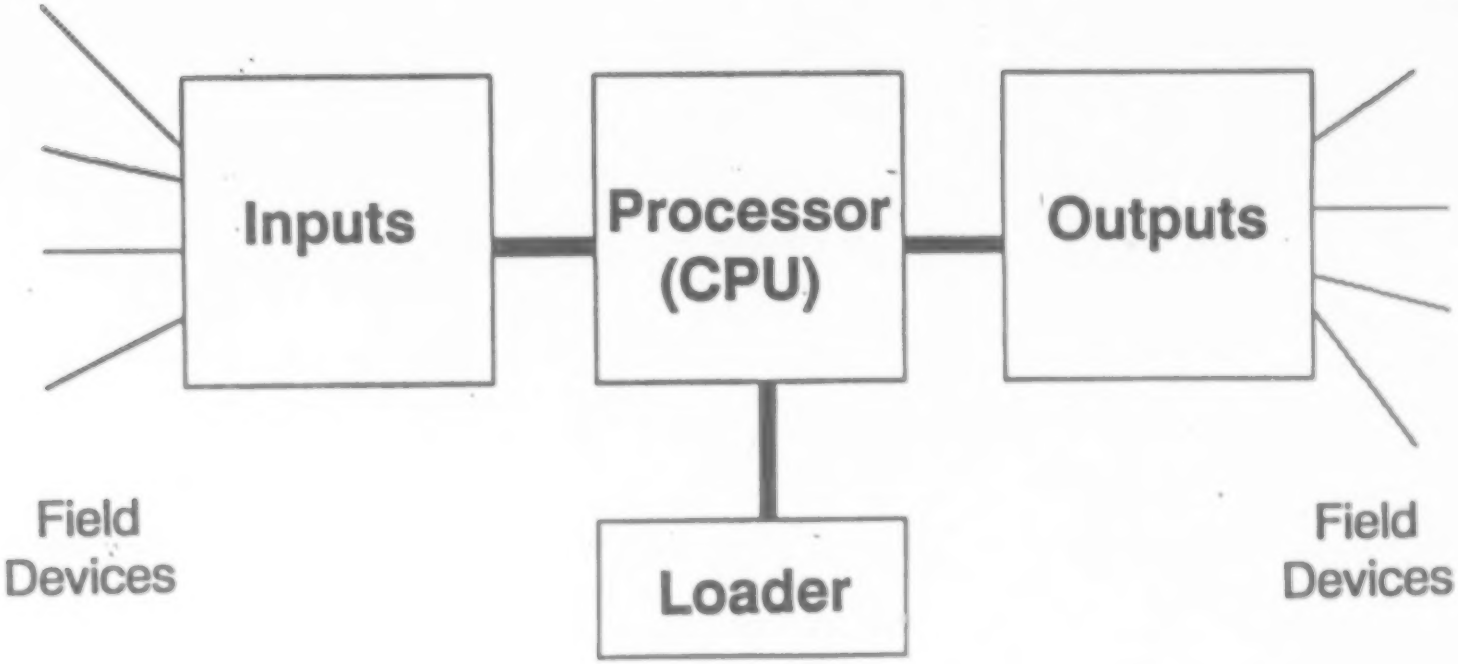
Automotive
Utilities and Oil Refineries
Food and Beverage
Glass, Rubber, Plastics, Chemicals, Paper, Agricultural and Engineering Products


L1
L2
L3
F
OL
T1
T2
T3
MOTOR
20 HP, 1.15 SF
3Ø / 460V / 60 Hz
27 AMP FLI
CFP
460V AC
CONTROL
POWER
TRANSFORMER
CFS
X1
X2
120 V AC
R

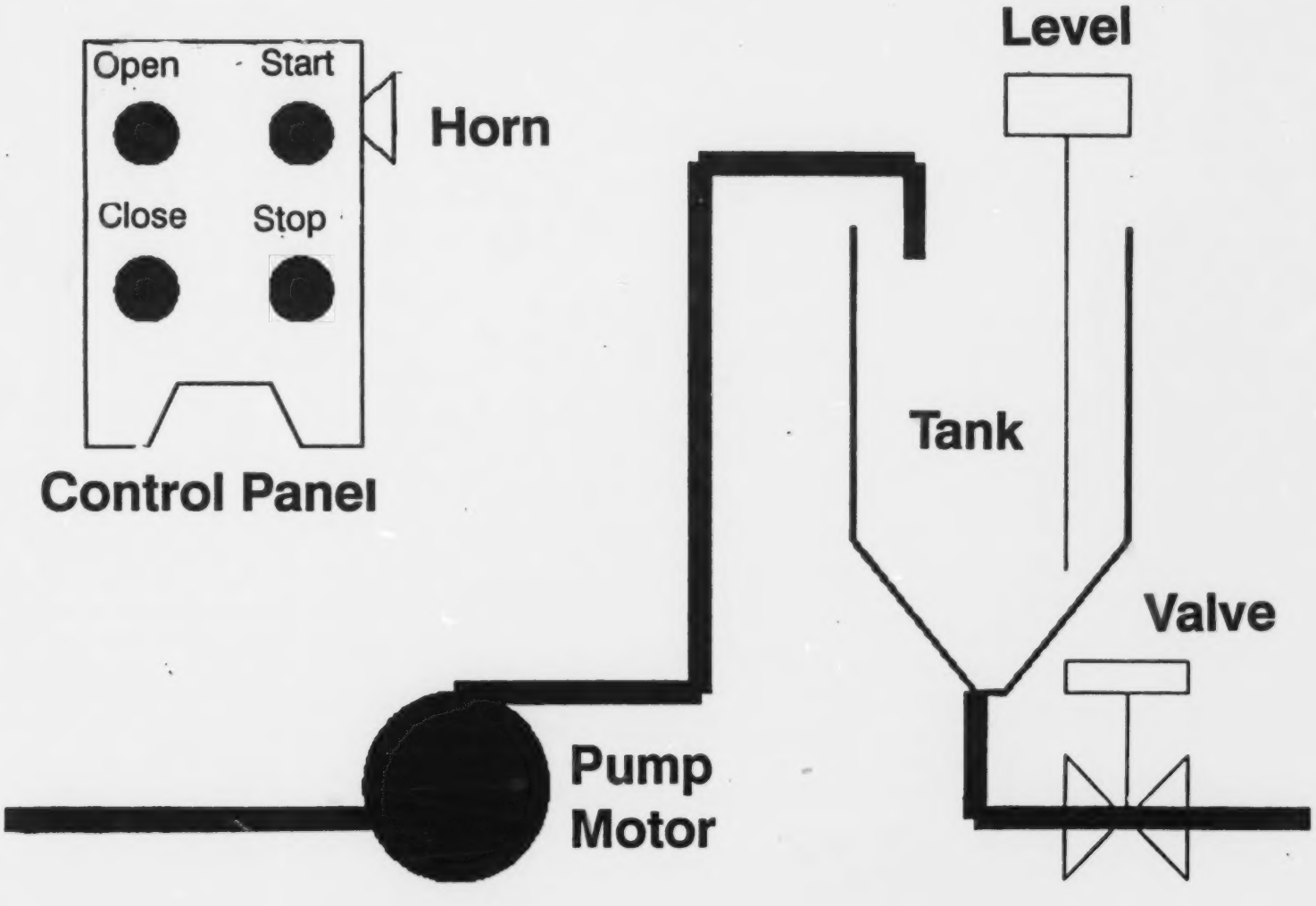

L1
L2
L3
F
OL
T1
T2
T3
MOTOR
20 HP, 1.15 SF
3Ø / 460V / 60 Hz
27 AMP FLI
CFP
460V AC
CONTROL
POWER
TRANSFORMER
R
CFS
X1
X2
120V AC
TS1
MACHINE
TEMP.
E. STOP
START
MCR
MCR
MAIN
CONTROL
RELAY
CONTROL
POWER
ON / ENABLED

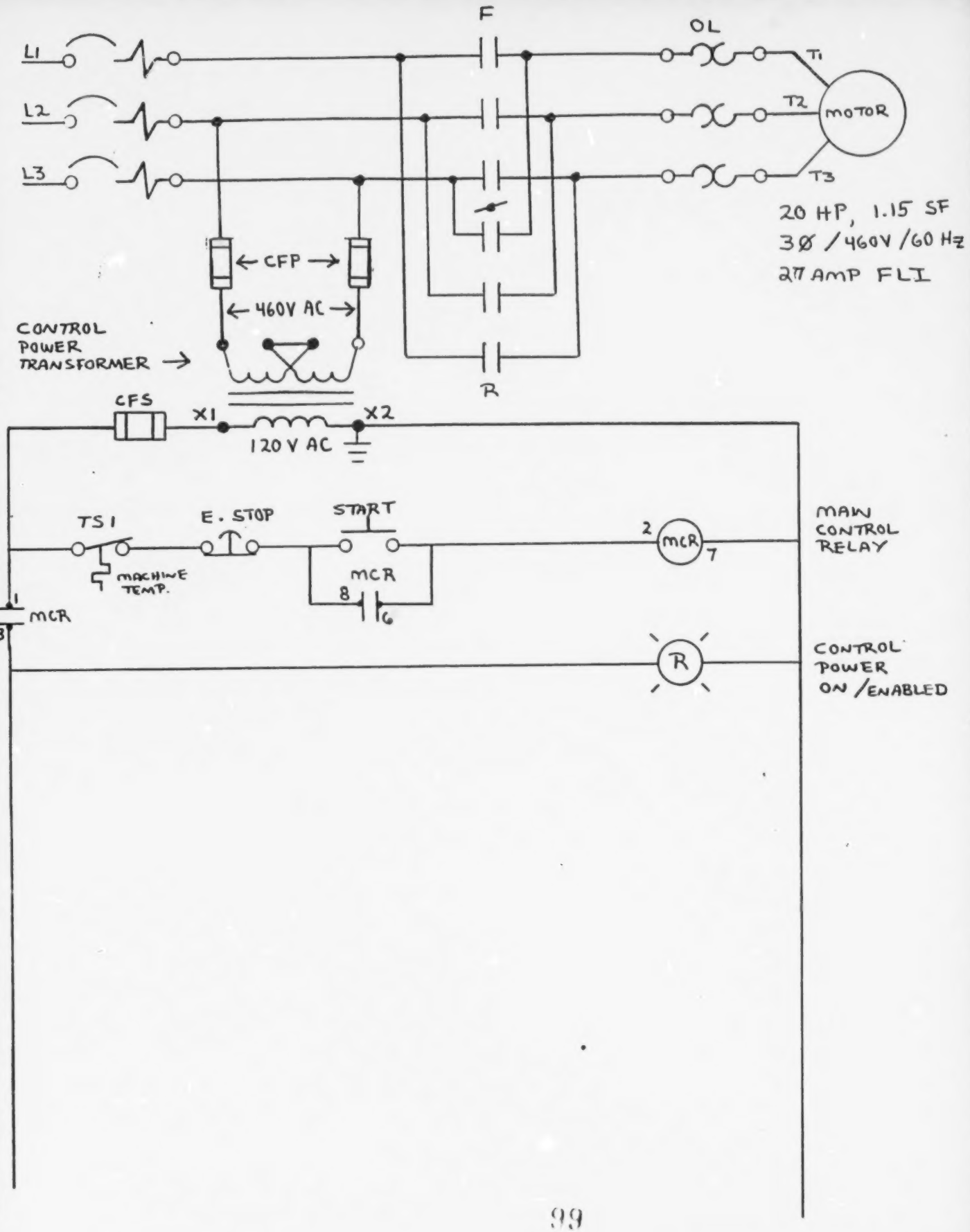

L1
L2
L3
F
OL
T1
T2
T3
MOTOR
20 HP, 1.15 SF
3Ø / 460V / 60 Hz
27 AMP FLI
CFP
460V AC
CONTROL POWER TRANSFORMER
R
CFS
X1
X2
120 V AC
TS1
MAXIMUM TEMP.
E. STOP
START
MCR
2
7
8
6
1
3
MAIN CONTROL RELAY
CONTROL POWER ON / ENABLED
A
FORWARD RUN INDICATION
OFF
FORWARD
REVERSE
X00
MR
FOR.
MF
OL
FORWARD
REV. JOG
X04
REV.
MR
REVERSE
B
REVERSE RUN INDICATION

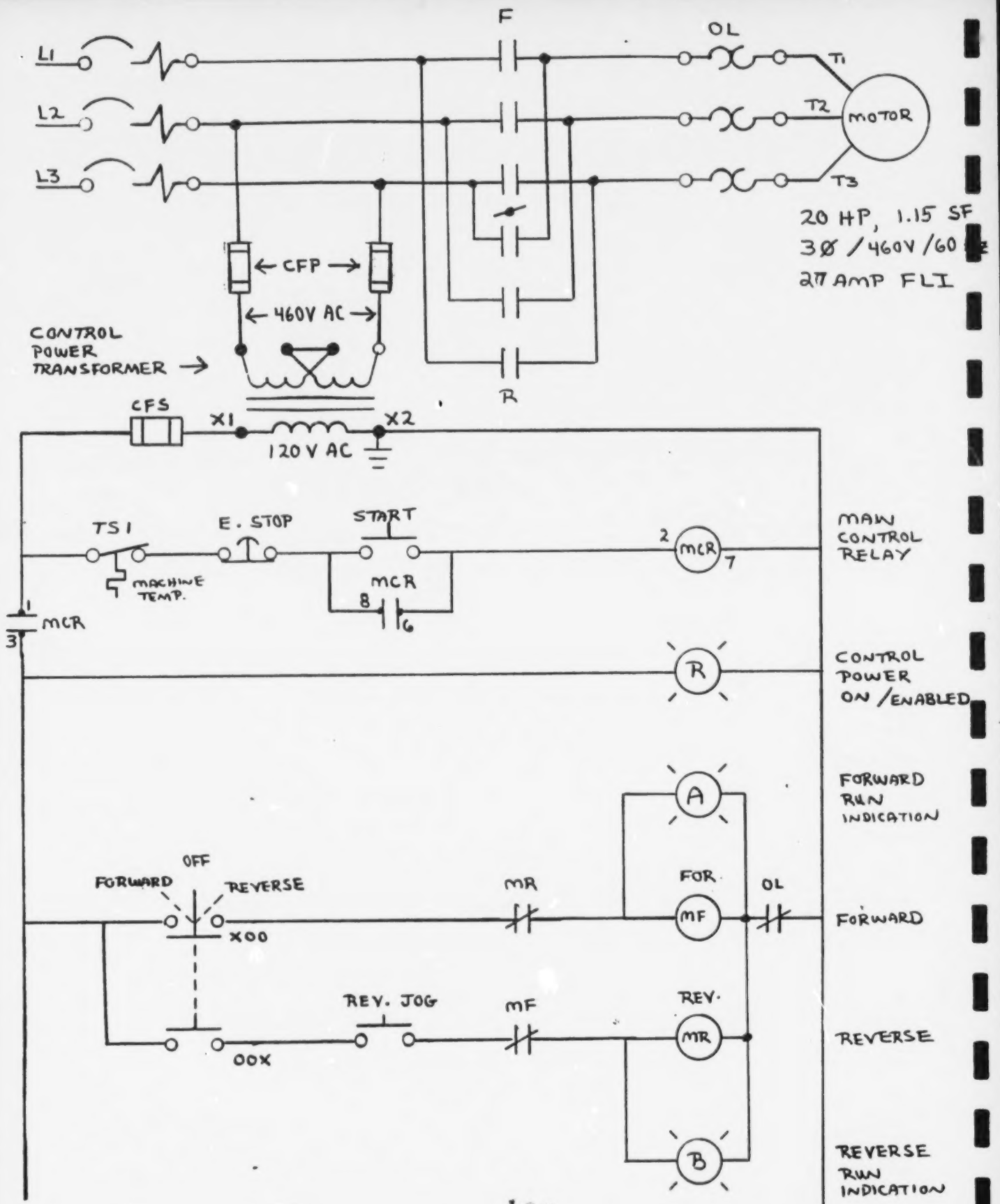
PLC System Components



I/O Example


Open
Start
Close
Stop
Horn
Control Panel
Level
Tank
Valve
Pump
Motor


F
OL
L1
L2
L3
T1
T2
T3
MOTOR
20 HP, 1.15 SF
3Ø / 460V / 60 Hz
27 AMP FLI
CFP
460V AC
CONTROL
POWER
TRANSFORMER
R
CFS
X1
X2
120 V AC
TS1
E. STOP
START
MACHINE
TEMP.
MCR
MCR
MAIN
CONTROL
RELAY
CONTROL
POWER
ON / ENABLED


L1
L2
L3
F
OL
T1
T2
T3
MOTOR
20 HP, 1.15 SF
3Ø / 460V / 60
27 AMP FLI
CFP
460V AC
CONTROL POWER TRANSFORMER
R
CFS
X1
X2
120 V AC
TS1
E. STOP
START
MACHINE TEMP.
MCR
MAIN CONTROL RELAY
CONTROL POWER ON / ENABLED
FORWARD RUN INDICATION
OFF
FORWARD
REVERSE
X00
MR
FOR
MF
OL
FORWARD
REV. JOG
00X
REV.
REVERSE
A
B
REVERSE RUN INDICATION

EVALUATION CHART

	SYS A	SYS B	SYS C
DESIGN TO MANUFACTURE			
INTERFACE			
PERFORMANCE			
CNC PARAMETERS			
LOGICAL SEQUENCE			
ESCAPE PROCEDURE			
FILE STRUCTURE			
SYSTEM THRU-PUT			
CAD BASED			
CAM BASED			
CAM/CAD BASED			
EDIT CODE			
EDIT GEOMETRY			
EDIT PARAMETERS			
DIRECT CAD INTERFACE			
INDIRECT CAD INTERFACE			
GENERIC POST			
CUSTOM POST			
USER SUPPORT			
COST W/O CAD			
CAD ADDL. COST			
POINT TOTALS			
COST			

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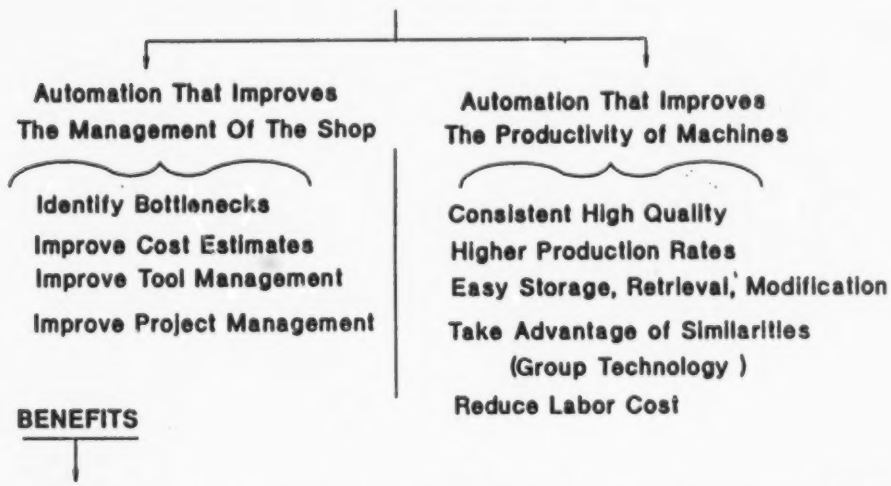
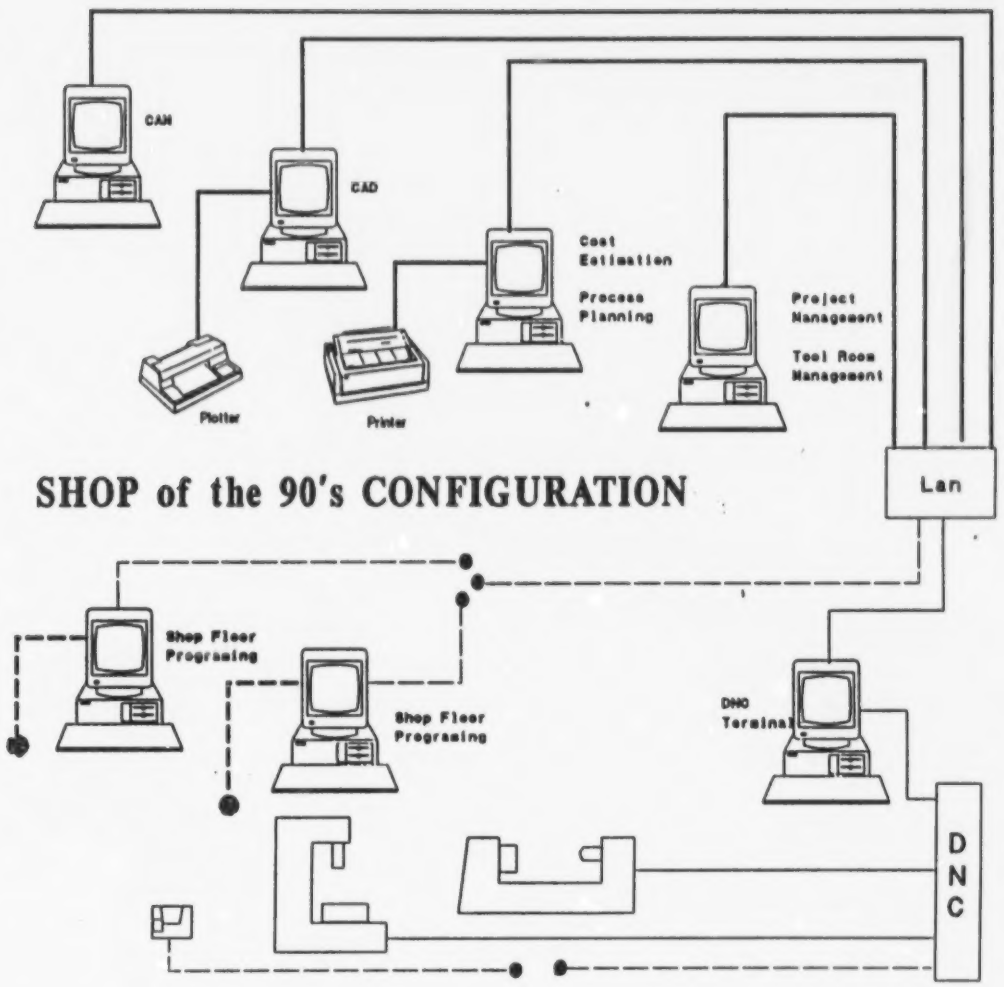
AUTOMATION FOR SMALL MACHINE SHOPS

Two Types of Automation



OVERALL: Reduce Thru-Put time and Maintain Consistent High Quality



SHOP of the 90's CONFIGURATION

Definition of System Requirements

I Part analysis. ..... Page

- A. Part description.
- B. Quantity/Part cycle.
- C. Projection for future.

II CNC machine tools. .....

- A. Machine tool types.
- B. Machine tool description.
- C. Controllers.
- D. Program transfer.
- E. Projection for future.

III CAM requirements. .....

- A. Part complexity.
- B. Macro capability.
- C. Parametric programming.
- D. Communication files.
- E. Operating system(s).

IV CAD system(s). .....

- A. In-House requirements.
- B. Communication files.
- C. Operating system(s).
- D. hardware.
- E. Projection for future.

V Workforce. .....

- A. Engineering/Drafting.
- B. CAD knowledgeable.
- C. CAM knowledgeable.
- D. Projection for future.

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II CNC Machine tools.

A. Machine tool types.

1. Milling. _____#
   a. 2 axis. ____#
   b. 3 axis. ____#
   c. 4 axis. ____#
   d. 5 axis. ____#
2. Turning. _____#
3. Electrical discharge. _____#
   a. Solid. ____#
   b. Wire. ____#
4. Grinding. _____#
   a. Surface. ____#
   b. Cylindrical. ____#
5. Laser. _____#
6. Router. _____#
   a. 3 axis. ____#
   b. 5 axis. ____#
7. Punch. _____#
8. Coordinate measure. _____#

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B. Machine tool description.

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____

C. Controllers.

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____

D. Program Transfer.

1. Tape/disk transfer. _____
2. Direct connect. _____
3. Local network. _____

E. Projection for future.

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5. CATIA (IBM). Y___ N___

6. GDF (IBM). Y___ N___

7. CADAM. Y___ N___

8. HPGL (Hewlett-Packard). Y___ N___

9. CGM (Computer graphics Metafile). Y___ N___

10 NFL (Anvil). Y___ N___

E. Operating system(s).

1. PC-Dos/MS-Dos. Y___ N___

2. UNIX. Y___ N___

3. Macintosh. Y___ N___

4. Other. _____

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IV CAD system(s).

A. In-house requirements.

1. Design and drafting of parts. _____%
2. CAD used for transfer to CAM. _____%
3. CAD used for detailed drawings. _____%

B. Communications files.

1. EMI (Ansii for MAPICS). Y___ N___
2. DXF (AutoCAD). Y___ N___
3. IGES. (universal). Y___ N___
4. CADL (CadKEY). Y___ N___
5. CATIA (IBM). Y___ N___
6. GDF (IBM). Y___ N___
7. CADAM. Y___ N___
8. HPGL (Hewlett-Packard). Y___ N___
9. CGM (Computer graphics Metafile). Y___ N___
10 NFL (Anvil). Y___ N___

C. Operating system(s).

1. PC-Dos/MS-Dos. Y___ N___
2. UNIX. Y___ N___
3. Macintosh. Y___ N___
4. Other. _____

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D. Hardware.

1. Microprocessor/Co-processor.

a. XT 8088/8087 processor. _____#

b. AT 80286/80287 processor. _____#

c. AT 80386/80387 processor. _____#

d. Macintosh. _____#

e. Other. _____#

2. Display device.

a. 12" monochrome/color. _____#

c. 14" Monochrome/color. _____#

e. 16" or larger color. _____#

2. Input devices.

a. Digitizer. _____#

b. Mouse. _____#

3. Plotter _____#

4. Scanner. _____#

E. Projection for future.

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V Workforce.

A. Engineering/Drafting.

1. Employees working as Design engineers . _____
2. Employees working as Production engineers. _____
3. Employees working as manual drafting. _____

B. CAD knowledgeable.

1. Employees working as CAD drafting/design. _____
2. Employees working as CAD drafting/update. _____
3. Employees working as CAD drafting/transfer. _____

C. CAM knowledgeable.

1. Employees working as CNC programmers. _____
2. Employees working as CAM programmers. _____

E. Projection for future. (yes no months)

1. Train manual programmers for CAM. Y___ N___ Ms___
2. Train CAD programmers for CAM. Y___ N___ Ms___
3. Hire additional CAM programmers. Y___ N___ Ms___
4. Train manual draftperson for CAD. Y___ N___ Ms___
5. Hire additional draftperson for CAD. Y___ N___ Ms___
6. Additional comments:

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Additional comments

I Part analysis.

II CNC machine tools.

III CAM requirements.

IV CAD requirements.

V Workforce.

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